THE
# HAWAIIAN
# PLANTERS' RECORD

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A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association

## The Science of *Hapai Ko.*

Though the sugar industry of Hawaii is commonly credited as having advanced to a high plane of scientific development, there are many phases of the industry to which we have never called the aid of scientific principles. Looking back at what science has accomplished for the industry here, and looking forward to what science may do along untried lines, one is more ready to believe that Hawaii can weather the foreign competition that is ahead of us.

What, for example, are the possibilities of applying scientific study to cane-loading?

Frederick W. Taylor, in "The Principles of Scientific Management," takes up what he calls "the science of handling pig iron." "This work," so he tells us, "is so crude and elementary in its nature that the writer firmly believes that it would be possible to train an intelligent gorilla so as to become a more efficient pig-iron handler than any man can be. Yet the science of handling pig-iron is so great and amounts to so much that it is impossible for the man who is best suited to this type of work to understand the principles of this science, or even to work in accordance with these principles without the aid of a man better educated than he is."

After deducing and applying these principles under the guidance of educated men, as was done at the Bethlehem Steel Company, the average day's work, that of loading 12½ tons of pig-

iron per man per day, was increased to 47 tons per man per day, and "the men were happier and better contented when loading at the new rate of 47 tons than they were when loading at the old rate of 12½ tons."

Now, if this applies to loading pig-iron, and if, as Mr. Taylor contends, "every single act of every workman can be reduced to a science," we have something to gain by evolving *the science of loading cane* and making practical use of it.

We have been concerned about what is going to happen when the *hapai ko* laborer becomes still scarcer than he now is, but we have never entered into a study of this strenuous plantation work. We have made little effort to make this work lighter,—more adaptable to the man of average physical endurance. We have devised no simple paraphernalia to assist him, if we except the *hapai ko* board, and the piece of sacking or rope which are universally employed. We have left the laborer to work out his own salvation—and ours along with his—and he has done all that could reasonably be expected of him.

We have not brought science to his aid,—we have not analyzed his day's work as the Bethlehem Steel Company did for their pig-iron loaders, experimenting and coaching them as to the proper rest intervals. We have not reduced cane-loading to a systematic study of the individual motions required, eliminating lost motion and waste effort as Frank B. Gilbreath did for his bricklayers, increasing the work to "350 bricks per man per hour; whereas the average speed of doing this work with the old methods was, in that section of the country, 120 bricks per man per hour."

Cane-loading is as yet an untried field for scientific endeavor—and an inviting one at that.

**Ammonia Treatment for Nematodes.**

In this issue we reproduce the article of Mr. Lovett of Oregon, which attracted our attention to the possibilities of fighting nematodes with ammonia. We have since read of a European beet field that was increased in yield from 4 to 37 tons per acre by controlling nematodes with ammonia solutions. Mr. Burgess finds that ammonia applied to Hawaiian soils is adsorbed in the surface layer very rapidly. This introduces a difficulty. The results of our tests are entirely problematical at this time.

## POISON GAS AND INSECT CONTROL.

Having addressed the Bureau of Entomology on the subject of using poison gases for insect control we now hear from Dr. L. O. Howard, who writes:

"Yours of the 12th of December has reached me, together with a copy of a clipping from the *Times-Picayune*. I have been unable to assure myself of the truth of the newspaper statement. This Bureau, however, is in correspondence with the Chemical Warfare Service, and is endeavoring to get some of their new gases for experimental use. Our correspondence has not yet reached a point where I can make any definite statements, but I shall bear your letter in mind."

## PLANT PATHOLOGY.—ITS RELATION TO AGRICULTURE.

All plant pathological problems, from a practical standpoint, are closely connected with the cultural phases of crop production. Production can not be successfully studied without a knowledge of the diseases affecting that particular crop, nor can the diseases of a crop be intelligently considered with reference to control measures except in conjunction with the cultural practices and with a knowledge of the conditions under which the crop is grown.—*Bulletin* 721, *U. S. Department of Agriculture.*

## NOTES ON THE CHINESE DRYINID* PARASITE OF THE SUGAR-CANE LEAFHOPPER.

By O. H. Swezey

This large black Dryinid parasite of the sugar cane leafhopper was discovered by Mr. Muir at Wei Chou, about 120 miles up the East River from Canton, China, in September, 1906. Leafhoppers were very scarce there, and only a very few were found parasitized by this Dryinid. These were taken to Macao, where

* *Pseudogonatopus hospes.* Described by Dr. Perkins in Ent. Bul. XI, p. 12, 1912.

Fig. 1. *Pseudogonatopus hospes*, female.

they were bred up on leafhoppers in cages on growing sugar cane in tubs until in sufficient numbers to forward to Honolulu.

Shipments of cocoons were received, with other parasite material, December 30, 1906, January 17 and February 19, 1907.

The adult parasites issuing from the cocoons were retained for breeding at the Experiment Station. They increased so slowly that the first colony to be sent out was not until June. Other colonies were sent out for liberation during July and August. These were mostly to the plantations of Oahu, but a few colonies were sent to the other islands also.

At best only small colonies were liberated in any place, and it was considered that this parasite failed to become established, for none were observed for several years. The first recovery was a single female found at the Waipio Substation, March 24, 1916. It was collected in Oahu Sugar Company's plantation in April; and in May three adult leafhoppers parasitized by this Dryinid were obtained in field 4 of the same plantation. In June of the same year it was noticed quite commonly in the cane at the Experiment Station grounds.

During 1917, recovery was made in a number of plantations, both on Oahu and the other Islands. Ewa, Oahu Sugar Co., and Honolulu Plantations on Oahu; Makee Sugar Co., Koloa Sugar Co., Kekaha Sugar Co., and Waimea Plantation on Kauai; Pioneer Mill Co., Wailuku Sugar Co., and Hawaiian Commercial and Sugar Co., on Maui; Hawi Mill & Plantation Co., on Hawaii. It was found at Olaa and Pahala, Hawaii; Hana, Maui; and Kahuku, Oahu, in 1918; and at Waialua in January 1919. So that now it is known to be widely established in the sugar plantation districts.

It is usually to be found in those plantations mentioned in which it is known to have become established, though it does not become abundant. Ordinarily not more than about 1% of the adult leafhoppers are found to be parasitized, though in one instance at Ewa Plantation, 9.21% were found to be parasitized in a lot of 532 leafhoppers caught in the field by sweeping with a net.

When cocoons of the parasite are collected in the field, hyperparasites issue from a large proportion of them. It is this which keeps this parasite from increasing to a great abundance, and reduces its efficiency.

This Dryinid attacks the adult leafhoppers (Fig. 2). Only rarely has a young leafhopper been found parasitized by it. In this respect it differs from the Fairchild parasite (*Echthrodelphax fairchildii*) and the Fiji Dryinid (*Haplogonatopus vitiensis*), both of which attack the young leafhoppers and only rarely an adult.

Fig. 2.

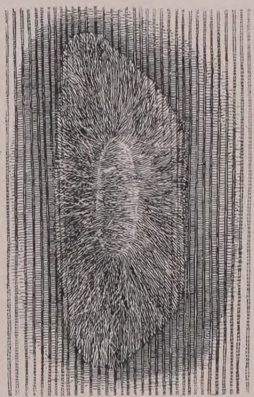


Fig. 3.

Fig. 2. Leafhopper parasitized by *Pseudogonatopus hospes.*
Fig. 3. Cocoon of *P. hospes* on cane leaf.

In parasitizing a leafhopper, the parasite catches and holds the leafhopper with her forelegs while she inserts the egg in the dorsal part of the abdomen. Having accomplished this, the leafhopper is released, and it goes on about its usual life while the parasite develops on its back resembling a black wart (Fig. 2). When the parasite larva becomes full-grown the leafhopper dies, and the parasite larva spins a white, oval, flat cocoon on a leaf (Fig. 3), or on the sugar cane stalk itself. The larva obtains its growth in one to two weeks. About three or four weeks are spent in the cocoon. Thus the life cycle is four to six weeks, which is approximately about the same as that of the leafhopper.

In the laboratory a female Dryinid lived 37 days and parasitized 153 leafhoppers, indicating the value of the parasite if its increase were not checked. The sexes are about in equal numbers, the male being winged but the female is wingless (Fig. 1). She would be greatly handicapped in accomplishing dispersal if

it were not for the fact that it is the adult leafhoppers which she parasitizes. They have been found early established in newly planted fields at some distance where they could not have migrated except by means of parasitized leafhoppers migrating by flight to the place before they were killed by the parasite larvae they were carrying.

This insect is an example of how an introduced insect (whether purposely or accidentally) may take a long time to become established and increase sufficiently as to be noticed. Colonies of the parasite were liberated in 1907, and it was not until 1916, nine years later, that any of them were seen. They must have been in existence somewhere all this time, but so scarce that none happened to be observed.

Similarly, no doubt, when some of the new immigrant insects are noticed for the first time, it may be several years after the first individuals arrived, and they have taken this length of time to become established under new conditions, and to become increased till numerous enough to be noticed.

## MIXED FERTILIZER VERSUS NITRATE OF SODA.

### HAKALAU EXP. NO. 2 (1919 CROP).*

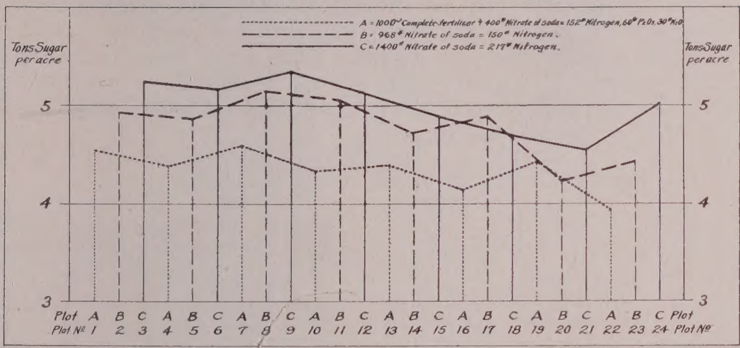
**We aimed, in this experiment, to test the relative value of applying mixed fertilizer as against (1) applying an amount of nitrate of soda equal in total amount of nitrogen; and (2) applying an amount of nitrate of soda equal in money value.**

### *SUMMARY.*

The test dealt with a first ratoon crop of Yellow Caledonia on a typical field of the Hilo Coast at about average elevation. The comparison was made between: (A) 1000 lbs. per acre of complete fertilizer in two equal doses during the first season and two equal doses of 194 lbs. per acre of nitrate of soda during second season, representing a total of 152 lbs. of Nitrogen, 60

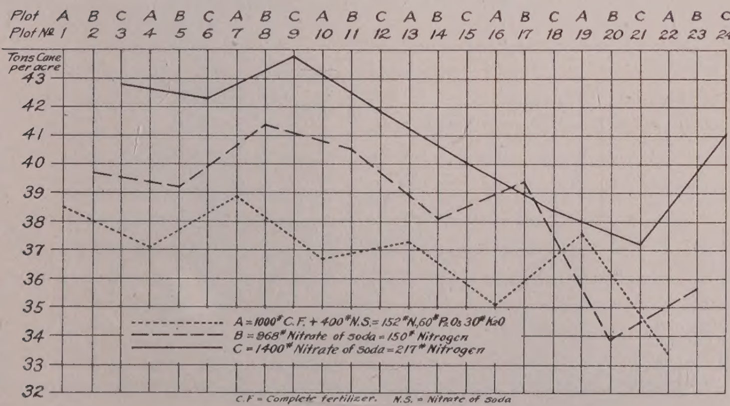
* Experiment planned by L. D. Larsen, J. A. Verret and W. P. Alexander.
* Experiment harvested by Robert Pahau.

MIXED FERTILIZER VS. NITRATE OF SODA
Hakalau Plantation Co. Exp.#2, 1919 Crop




lbs. of Phosphoric Acid and 32 lbs. of Potash; (B) Four equal doses of 242 lbs. per acre of Nitrate of Soda, representing a total of 150 lbs. of Nitrogen; (C) Four equal doses of 350 lbs. per acre of Nitrate of Soda, representing 217 lbs. of Nitrogen, this latter amount of Nitrate being equal in money value at a pre-war basis to the complete fertilizer.

MIXED FERTILIZER VS. NITRATE OF SODA
Hakalau Plantation Co. Exp.#2, 1919 Crop



The results show that the added phosphoric acid and potash were of no benefit to this crop.

The results furthermore show a decided advantage where there was substituted for the potash and the phosphoric acid an equal money value of nitrogen. The gains produced were very consistent for all plots. Every C plot gave a higher yield than its adjoining A plot, the average increase being 0.67 ton of sugar per acre.

TABLE I. SUMMARY OF YIELDS FOR EACH TREATMENT.

| Plot | No. of Plot | TREATMENT | Tons Cane per Acre | Q. R. | Tons Sugar per Acre | Gain Over A | |
|---|---|---|---|---|---|---|---|
| | | | | | | Cane | Sugar |
| A | 8 | 1000# C.F. + 398# N. S. = 152# N. 60# $P_2O_5$, 30# $K_2O$. | 36.86 | 8.47 | 4.35 | ... | ... |
| B | 8 | 968# N. S. = 150# N........ | 38.53 | 8.04 | 4.79 | 1.67 | .44 |
| C | 8 | 1400# N. S. = 217# N........ | 40.98 | 8.17 | 5.02 | 4.12 | .67 |

## *DETAILED ACCOUNT.*

*Object.*

To determine the relative value of mixed fertilizer and nitrate of soda:

(a) When applying equal amounts of nitrogen, and nitrate of soda;

(b) When applying equal money values.

*Location.*

Hakalau Plantation Co., Field 31A, on Hamakua side of field road; elevation about 1000 feet.

*Layout.*

No. of plots=24. Size of plots=1/10 acre, each plot consisting of five furrows, 5 feet wide and 174.2 long. Each furrow =1/50 acre in area.

*Crop.*

Yellow Caledonia, first ratoon (long).

## MIXED FERTILIZER VS. NITRATE OF SODA

### Hakalau Plantation Co. Exp. #2, 1919 Crop

| Plot | | Tons p.a. Cane | Tons p.a. Sugar |
|---|---|---|---|
| 1 | A | 38.57 | 4.55 |
| 2 | B | 39.71 | 4.94 |
| 3 | C | 42.82 | 5.24 |
| 4 | A | 37.18 | 4.39 |
| 5 | B | 39.18 | 4.87 |
| 6 | C | 32.35 | 5.18 |
| 7 | A | 38.97 | 4.60 |
| 8 | B | 41.47 | 5.16 |
| 9 | C | 43.81 | 5.36 |
| 10 | A | 36.73 | 4.34 |
| 11 | B | 40.69 | 5.06 |
| 12 | C | 41.98 | 5.14 |
| 13 | A | 37.30 | 4.40 |
| 14 | B | 38.10 | 4.74 |
| 15 | C | 40.05 | 4.90 |
| 16 | A | 35.13 | 4.15 |
| 17 | B | 39.40 | 4.90 |
| 18 | C | 38.47 | 4.71 |
| 19 | A | 37.61 | 4.44 |
| 20 | B | 33.99 | 4.23 |
| 21 | C | 37.28 | 4.56 |
| 22 | A | 33.39 | 3.94 |
| 23 | B | 35.71 | 4.44 |
| 24 | C | 41.04 | 5.02 |

Hilo side

Field Road

3' path

25'

174'

Mauka

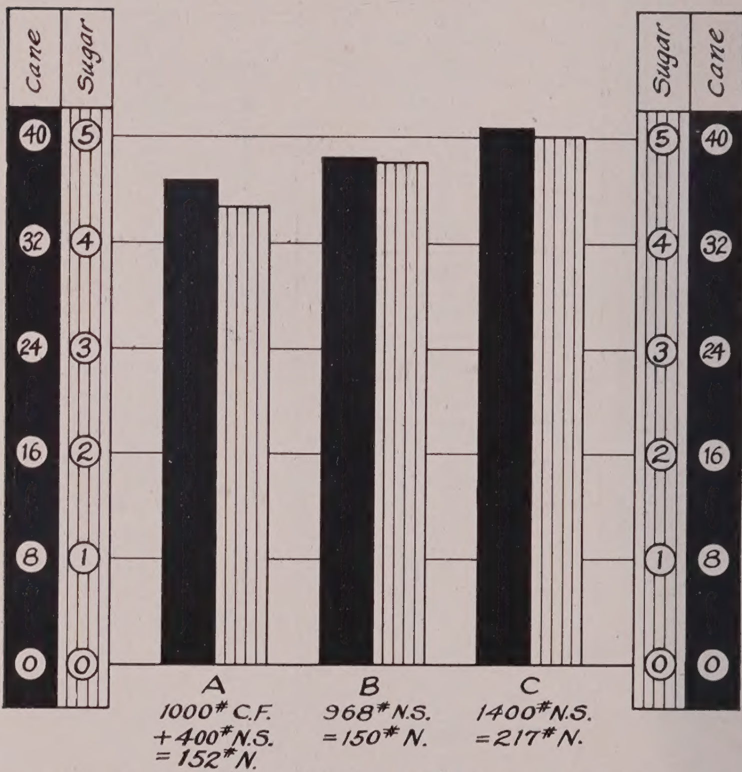
Field 31 A

1st ratoons, long

24 plots — each 1/5 acre consisting of 5 furrows. Each furrow = 5' wide & 174' long.

Honokaa side

## *Mixed Fertilizer vs. Nitrate of Soda*
### *Hakalau Plantation Co. Exp. 2, 1919 Crop*




*1000# Complete fertilizer + 400# Nitrate of soda = 152# Nitrogen, 60# $P_2O_5$, 30# $K_2O$.*

*Plan.*

FERTILIZATION—POUNDS PER ACRE.

| Plots | May 15, '17 | Sept. 15, '17 | Jan. 30, '18 | May 15, '18 | Total Lbs. Nitrogen per Acre |
|---|---|---|---|---|---|
| A | 500 # C. F. | 500 # C. F. | 194 # N. S. | 194 # N. S. | 150 # N. |
| B | 242 # N. S. | 242 # N. S. | 242 # N. S. | 242 # N. S. | 150 # N. |
| C | 350 # N. S. | 350 # N. S. | 350 # N. S. | 350 # N. S. | 217 # N. |

Hakalau Sugar Co. Mixed Fertilizer: 9% Nitrogen $\begin{cases} 3\frac{1}{4} \text{ from Nit.} \\ 3\frac{1}{2}\% \text{ from Sul.} \\ 2\ \% \text{ Organic.} \end{cases}$

6% $P_2O_5$
3% $K_2O$

Nitrate of soda = 15.5% N.

## *Progress.*

Experiment laid out by L. D. Larsen in 1915.
Previous crop harvested March 8, 1917.
Fertilizations according to the plan were made on the following dates:
First application, June 5, 1917.
Second application, October 2, 1917.
Third application, January 29, 1918.
Fourth application, May 23, 1918.
January 27, 1919, the experiment was harvested.
Weighing was done in the field by bundle, every third bundle being weighed.

To obtain net weight from gross, deductions were made for tare as obtained by taring one bundle from each plot. The per cent. discount for each plot was different for each one.

For juice samples, one stick was taken from every fifth bundle.

In taking these, as far as possible, a top and a bottom piece were taken consecutively.

The twenty-four samples were run through the fourth mill. Afterwards composite samples were made for analysis. The ones that had the same treatment were put together.

Juice tests were made by Mr. R. Elliot, Chemist, Hakalau Plantation Co.

TABLE 2.

DETAILED RESULTS BY PLOT, INCLUDING QUALITY OF JUICES.

| Plot. | Treatment. | Tons Cane per Acre. | Tons Sugar per Acre. | Q. R. | ° Brix. | Sucrose. | Purity. |
|---|---|---|---|---|---|---|---|
| 1 A | 1000 lbs. C. F. + 400 lbs. N. S. | 38.57 | 4.55 | 8.47 | 18.7 | 15.9 | 85.0 |
| 2 B | 968 lbs. N. S. | 39.71 | 4.94 | 8.04 | 18.9 | 16.5 | 87.3 |
| 3 C | 1400 lbs. N. S. | 42.82 | 5.24 | 8.17 | 18.5 | 16.2 | 87.6 |
| 4 A | 1000 lbs. C. F. + 400 lbs. N. S. | 37.18 | 4.39 | 8.47 | 18.7 | 15.9 | 85.0 |
| 5 B | 968 lbs. N. S. | 39.18 | 4.87 | 8.04 | 18.9 | 16.5 | 87.3 |
| 6 C | 1400 lbs. N. S. | 42.35 | 5.18 | 8.17 | 18.5 | 16.2 | 87.6 |
| 7 A | 1000 lbs. C. F. + 400 lbs. N. S. | 38.97 | 4.60 | 8.47 | 18.7 | 15.9 | 85.0 |
| 8 B | 968 lbs. N. S. | 41.47 | 5.16 | 8.04 | 18.9 | 16.5 | 87.3 |
| 9 C | 1400 lbs. N. S. | 43.81 | 5.36 | 8.17 | 18.5 | 16.2 | 87.6 |
| 10 A | 1000 lbs. C. F. + 400 lbs. N. S. | 36.73 | 4.34 | 8.47 | 18.7 | 15.9 | 85.0 |
| 11 B | 968 lbs. N. S. | 40.69 | 5.06 | 8.04 | 18.9 | 16.5 | 87.3 |
| 12 C | 1400 lbs. N. S. | 41.98 | 5.14 | 8.17 | 18.5 | 16.2 | 87.6 |
| 13 A | 1000 lbs. C. F. + 400 lbs. N. S. | 37.30 | 4.40 | 8.47 | 18.7 | 15.9 | 85.0 |
| 14 B | 968 lbs. N. S. | 38.10 | 4.74 | 8.04 | 18.9 | 16.5 | 87.3 |
| 15 C | 1400 lbs. N. S. | 40.05 | 4.90 | 8.17 | 18.5 | 16.2 | 87.6 |
| 16 A | 1000 lbs. C. F. + 400 lbs. N. S. | 35.13 | 4.15 | 8.47 | 18.7 | 15.9 | 85.0 |
| 17 B | 968 lbs. N. S. | 39.40 | 4.90 | 8.04 | 18.9 | 16.5 | 87.3 |
| 18 C | 1400 lbs. N. S. | 38.47 | 4.71 | 8.17 | 18.5 | 16.2 | 87.6 |
| 19 A | 1000 lbs. C. F. + 400 lbs. N. S. | 37.61 | 4.44 | 8.47 | 18.7 | 15.9 | 85.0 |
| 20 B | 968 lbs. N. S. | 33.99 | 4.23 | 8.04 | 18.9 | 16.5 | 87.3 |
| 21 C | 1400 lbs. N. S. | 37.28 | 4.56 | 8.17 | 18.5 | 16.2 | 87.6 |
| 22 A | 1000 lbs. C. F. + 400 lbs. N. S. | 33.39 | 3.94 | 8.47 | 18.7 | 15.9 | 85.0 |
| 23 B | 968 lbs. N. S. | 35.71 | 4.44 | 8.04 | 18.9 | 16.5 | 87.3 |
| 24 C | 1400 lbs. N. S. | 41.04 | 5.02 | 8.17 | 18.5 | 16.2 | 87.6 |

W. P. A. and J. A. V.

## A DANGEROUS BINDWEED.*

The California Morning Glory has become established near the mill on the road-bed of the Kahului Railroad. This is a new plant immigrant and if allowed to spread unhampered, is certain to become one of the most troublesome weeds in the cane fields of Maui. Immediate steps should be taken to eradicate it while it is still restricted to small areas.

As the weed has been found only along the railroad tracks it is reasonably certain that the trains and freight which they carried were the agencies that distributed the original seed. This being the case, it is quite possible that the weed is already established at many points along the railroad. This should be at once determined through a careful inspection of the entire right-of-way by a competent man or group of men and each and every point of infection properly marked. This having been done adequate treatment should be applied at each point to eliminate the pest.

This plant produces underground stems or stolons from which new plants spring at intervals. These stolons may attain great length and often travel at a considerable depth beneath the surface of the soil. A small fragment of one of these stolons, if left in the ground, is sufficient to start a new colony of the weed. To effectually eradicate this plant it is necessary, therefore, to remove every particle of these stolons from the soil or to destroy them in position by chemical or mechanical treatment of the soil.

If the plants occurred in an open piece of ground apart from obstructions, steaming the soil would undoubtedly prove the most rapid as well as the most effective means of destroying the plants, at the same time improving instead of injuring the agricultural condition of the soil. In the case in question, however, the plants occur between and under the railroad ties and rails and it is therefore difficult or impossible to get at them with a steaming device.

If the infected areas were dug over at intervals of a month or six weeks and the stolons carefully removed each time, it should be possible to effect a complete eradication of the plant in the course of six months or a year at most. Nut grass was eliminated from the cultivated land at the Pathology Plot in Honolulu by this method.

The only other method to be considered is the use of chemical weed killers such as crude petroleum and arsenic solutions. I am told that the former has been used successfully for the destruc-

* From a report by Dr. Lyon on "Certain Problems Met With on the Plantation of the Maui Agricultural Company."

tion of nut grass in roadways, two applications being sufficient to do the work. I should expect more certain results from an arsenic solution than from the petroleum. A strong solution of arsenite of soda should be employed, and this may be prepared according to the following formula:

"*Stock Solution*:

1. 5 lbs. white arsenic
2. 5 lbs. sal soda
   or
   1 lb. caustic soda
   or
   2½ lbs. soda ash
3. 2½ gallons water.

Boil this for 10 or 15 minutes or until solution is clear. Best results are obtained by dissolving the soda first and then adding the arsenic gradually as the liquid comes to a boil."

In treating the morning glory, dilute this stock solution to 20 gallons and apply in such quantity as to saturate the soil around the main plant and all of its secondaries so as to kill the intervening stolons.

Petroleum and strong arsenic solutions should not be used in this manner in the field as they seriously injure the soil, but they can, of course, be used with impunity on the railroad road-bed.

To make the campaign against this weed successful, it will be necessary that the infected areas be inspected at intervals and the treatments repeated until the last vestige of the plant has been destroyed.

## ACETYLENE GAS GENERATOR FOR LABORATORY.

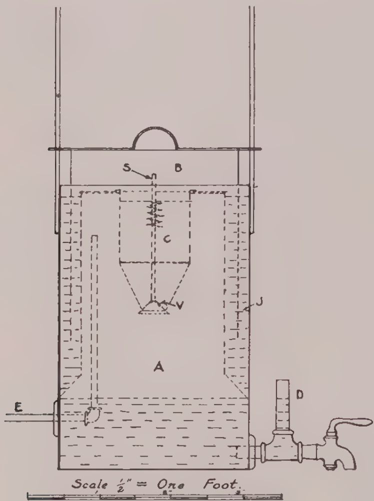
By G. F. Murray.

I have designed and have in operation at Pepeekeo an acetylene gas generator which has given excellent results, being extremely economical and needing no care except for removing mud and supplying fresh water once or twice a week; one charge of 10 pounds of carbide usually lasting three weeks.

I find I can polarize molasses solutions much more accurately with the acetylene light than with the tungsten lamp.

We have used it several times to light the laboratory during a shut down, when we had no electric lights.

This generator consists of three parts, a lower circular tank "A" having a water jacket "J" extending from the top to within 6″ of the bottom. A container "C" for carbide, resting on the inner edge of water jacket; and a gas reservoir "B," superimposed on "A" and floating in water jacket, being held in place by guide posts on each side.




Tank "A" has a gas outlet "E," and a water pipe and cock at "D" through which mud and water are drawn off and fresh water added as necessary.

Container "C" consists of a cylindrical vessel with a cone-shaped valve "V" in bottom. By means of a coil spring on valve stem "S," the valve is kept closed.

In operation, "A" is filled to a depth of 6″ with water. Carbide container "C" is filled with granulated carbide and put in place. Reservoir "B" is floated in water jacket and gas line opened, allowing "B" to fall. This depresses valve stem "S," and admits the carbide into the lower compartment, where gas is generated. When the gas pressure is sufficient to raise the reservoir the valve closes. This operation is repeated as the gas is used. Any pressure desired may be had by adding weights to reservoir.

# CAN WE PREDICT PROBABLE FERTILITY FROM SOIL BIOLOGICAL DATA?

By P. S. Burgess.

Among the many processes active in soils, whereby both mineral and organic materials are rendered available for absorption by the higher plants, none are more important than the normal functioning of bacteria and fungi. In fact we know that any soil, deprived of its microscopic flora, soon becomes a barren waste incapable of producing normal plants. Bacteria and fungi are very low forms of plant life requiring the same mineral elements for their growth and multiplication as do the higher crop plants with which we are more directly interested. Is it not possible, therefore, that there may exist a relationship or a correlation between certain bacterial activities and the actual crop-producing powers of soils? In an endeavor to answer this question, several investigators during the past few years have attempted to correlate the fertility (or crop producing power) of soils with their abilities to biologically produce ammonia, nitrates or carbon dioxide, and a few soil scientists have been fairly successful in predicting fertility, or lack of it, from such biological data. Brown (3; 4)* at the Iowa Agricultural Experiment Station; Lipman (13) at California; Lyon, Bizzell and Conn (18) at New York; Gainey (8) at Kansas; Given (9) at Pennsylvania; Ashby (1) and Russell and Hutchinson (21), in England; and Vogel (22, 23, 24), and several other German investigators may be cited as having contributed to our knowledge along these lines of work. That there is often little agreement, either in the data obtained or in the conclusions drawn therefrom by these investigators, is seen by a comparison of their several efforts. This is doubtless due, at least in large part, to the dissimilarity of methods employed. As has been inferred, the attempt has been made in the work above cited to in some degree correlate the yields from various soils with their abilities to biologically transform nitrogen compounds. The organic material used has thus usually remained constant in kind and amount while the soils have varied. Conversely, by allowing the soil to remain constant, it is possible to compare the availabilities of different nitrogenous fertilizers (especially organics) biologically, and at present such methods are largely used, either by determining

* Reference is made by number to "Literature cited," p. 265.

ammonifiability, as proposed by J. G. Lipman (17) or better, by determining nitrifiability as advanced by Lipman and Burgess (14:15). Purely chemical methods, as the old alkaline potassium permanganate method (2), are no longer considered reliable for this purpose. Of course, the absolute method of determining fertilizer availability is by carefully controlled vegetation tests, but as these are both costly and time consuming, and as such experiments have shown the validity of the bacteriological tests above indicated, the latter are now very widely used.

As has been pointed out by the writer and by others, Hawaiian soils are decidedly different, physically, chemically, and biologically, from mainland soils. Many more or less unproductive soils are received at this laboratory from time to time with inquiries as to the causes for conditions noted in the field. Unless a preliminary examination shows, at once, the probable cause of infertility, the soil sample is usually run for available potash and phosphoric acid (sometimes for total phosphoric acid), nitrate nitrogen, total nitrogen, the lime requirement (Veitch method) if acid, and the alkali content is determined if any excess of soluble salts is present. Aside from these chemical tests, it is always desirable to learn something as regards the biological properties of the soils submitted. The question thus naturally presents itself, "Which of the several biological processes occurring in soils, *i.e.*, ammonification, nitrification, nitrogen fixation, or carbon dioxide production, is the best to use as a criterion of fertility in our Hawaiian soils?" In an endeavor to answer this question the following work was planned and carried through.

## EXPERIMENTAL

About fifteen or twenty pounds of surface soil were obtained from each of the following sugar plantations:

TABLE 1.

SOILS EMPLOYED.

| Lab. No. | Plantation | Description of Soil* |
|---|---|---|
| 1 | Hawaiian Sugar Co. .. | Red clay loam. Fairly fertile. |
| 2 | Hawi Mill & P. Co. .. | Brown silty clay loam. Very fertile. |
| 3 | Laupahoehoe Sug. Co... | Brown silty clay loam. Very good soil. |
| 4 | Honomu Sug. Co. .... | Brown silty clay loam. Very good soil. |
| 5 | Kipahulu Sug. Co. .... | Grayish clay loam. Poor soil. |
| 6 | Waipio Substation .... | Light brown silt loam. Fairly fertile. |
| 7 | Honomu Sug. Co. .... | Light brown clay loam. Poor; not as good as No. 4. |
| 8 | H.S.P.A. Exp. Sta., Honolulu ............ | Dark brown clay loam. Very good soil. |
| 9 | Pacific Sug. Mill ..... | Light brown clay loam. Poor, acid soil. |

* The descriptions of these soils are based upon the crops of sugar cane which they are producing in the field with normal fertilization (1000 to 1500 lbs. complete fertilizer per acre).

Soil No. 2 was probably the most fertile one used, although soils Nos. 1, 8, 4, 6, and 3 were from very good fields. Soil No. 9 was probably the least fertile, while Nos. 5 and 7 were but slightly better. As soon as received at the laboratory, the soils were partially air dried in the shade and sifted through a 5 m.m. mesh sieve, the usual precautions being taken to prevent contamination. The soils were all subjected to the following tests: ammonification, nitrification, nitrogen fixation and total water soluble nitrogen production. The determinations of the amounts carbon dioxide formed were not here attempted for it has been recently shown (19) that there is a more or less definite correlation between the amounts of $CO_2$ produced by a soil's flora from a given amount of organic material and the quantities of ammonia simultaneously evolved, and further, the accurate determination of $CO_2$ as given off from bacterial cultures is not only most difficult, but also the incubation conditions under which the soils must be held during the test are so artificial as to detract somewhat from the value of data so obtained. We also know that a considerable proportion of the $CO_2$ evolved from soils is due to mold action (20) and the part played by fungi in soil fertility is at present imperfectly known.

The following fertilizers were used in ascertaining the ammonifying, nitrifying and the total water soluble nitrogen producing efficiencies of the above soils: dried blood (13.5% N), alfalfa meal (3.0% N), and fish scrap (7.73% N).

Triple portions (50 grams for the ammonifications and 100 grams for the nitrifications and total water soluble nitrogens) of each of the soils were weighed out into sterile glass tumblers and covered with Petri dishes, for each of the three fertilizing materials above given, in so far as the amounts of the soils on hand permitted. As the tables following will show, the samples of soil taken proved to be too small (due to the removal of stones and trash when sifted) to always allow for the use of the three fertilizing materials, hence, in many cases, the fish scrap treatments were omitted.

Three incubation periods were employed for the ammonification, nitrification and total water soluble nitrogen tests, *i.e.*, 10 days, 20 days and 30 days. At the end of each period one culture of each series was removed and analyzed. The blanks on the untreated soils have in each case been subtracted from the results as tabulated in the tables which follow.

*The Ammonification Results.* The usual direct soil culture, or "beaker method," was here employed. To 50 grams of soil were added 1 gram of each of the organic materials, irrespective of their nitrogen contents. The incubation temperature was

28° C. As stated above, three different incubation periods were allowed, *i.e.*, 10 days, 20 days and 30 days. At the end of each period one culture using dried blood, one using alfalfa meal and one using fish scrap, were analyzed for ammonia by the usual magnesium oxide distillation method. The results secured at the end of each incubation period and with each fertilizer used are presented in Table II, which follows. In the column "Laboratory Numbers," the numbers refer to the soils employed, and correspond to those given in Table I, while the letters refer to the fertilizing materials used, *i.e.*, A. dried blood; B, alfalfa meal; and C, fish scrap.

TABLE 2.

THE AMMONIFICATION RESULTS.

| | 10-day Incubation Period | | 20-day Incubation Period | | 30-day Incubation Period | |
|---|---|---|---|---|---|---|
| Lab. No. | Mgms. added N. Ammo'fied | % added N. Ammo'fied | Mgms. added N. Ammo'fied | % added N. Ammo'fied | Mgms. added N. Ammo'fied | % added N. Ammo'fied |
| 1 A | 76.4 | 56.6 | 50.4 | 37.3 | 35.6 | 26.4 |
| 1 B | 6.7 | 22.3 | 3.6 | 12.0 | 2.8 | 9.3 |
| 1 C | 41.4 | 53.8 | . . . | . . . | 24.9 | 32.3 |
| 2 A | 100.2 | 74.2 | 65.5 | 48.5 | 59.9 | 44.4 |
| 2 B | 14.8 | 49.3 | 12.0 | 40.0 | 5.6 | 18.7 |
| 3 A | 57.1 | 42.3 | 63.0 | 46.7 | 46.5 | 34.4 |
| 3 B | 12.9 | 43.0 | . . . | . . . | 4.8 | 16.0 |
| 4 A | 74.5 | 55.2 | 57.4 | 42.5 | 40.0 | 29.6 |
| 4 B | 9.8 | 32.7 | 11.5 | 38.3 | 2.5 | 8.3 |
| 5 A | 26.6 | 19.7 | 29.7 | 22.0 | 25.8 | 19.1 |
| 5 B | 1.4 | 4.7 | 1.1 | 3.6 | 2.2 | 7.3 |
| 5 C | 16.0 | 20.8 | 1.9 | 2.5 | 4.4 | 5.7 |
| 6 A | 68.6 | 50.8 | 70.0 | 51.8 | 46.5 | 34.4 |
| 6 B | 11.2 | 37.3 | . . . | . . . | 5.3 | 17.7 |
| 7 A | 47.6 | 35.3 | 61.0 | 45.2 | 45.9 | 34.0 |
| 8 A | 57.7 | 42.7 | 15.4 | 11.4 | 31.9 | 23.6 |
| 8 B | 9.5 | 31.7 | . . . | . . . | 1.7 | 5.6 |
| 9 A | 75.9 | 56.2 | 74.2 | 55.0 | 80.1 | 59.3 |
| 9 B | 14.0 | 46.7 | 20.7 | 69.0 | 21.6 | 72.0 |

The usual incubation period for ammonification studies is from 7 to 10 days and the most common organic material used for this test is finely ground dried blood. For this reason, let us briefly discuss the relative fertilities of the various soils as shown when dried blood was used and the analyses were made at the end of 10 days. Soil No. 2, which is certainly one of the most fertile soils used (if not the very best), heads the list, followed by soils

Nos. 1, 9, 4, 6, 8, 3, 7 and 5. Soil No. 5 is certainly one of the poorest ones, and it shows the lowest ability to ammonify, but, on the other hand, soil No. 9 is also very poor, while it is third on the list, lacking but a few tenths of a per cent. of being next to the best soil noted. Soil No. 3, while it stands near the lower end of the list, is nevertheless a very good producing soil. Many of the intermediate soils are, however, quite close together in the percentages of added nitrogen which they have been able to ammonify.

Where finely ground alfalfa meal (a vegetable protein material) was used as the source of nitrogen, certain changes in the relative standing of the soils are seen, although No. 2 still heads the list and No. 5 concludes it as before. Soil No. 1, which before was next to No. 2, is now next to the last, while No. 3, which with dried blood did poorly, ranks third. Soil No. 9 holds second place while it was a close third before, notwithstanding the fact that it is a very poor, acid, upland soil. It may be said here that there was considerable mold growth noticed in the No. 9 cultures (especially when dried blood was used), hence probably much of the ammonia here produced was of fungal origin. With alfalfa meal the soils rank as follows: 2, 9, 3, 6, 4, 8, 1, and 5.

Fish scrap was only used in two instances, but here it shows soil No. 1 to be much better than soil No. 5, which is in accordance with fact and with other tests.

As will be seen, in almost all cases the amounts of ammonia found at the end of the 20 and 30 day incubation periods are much lower than those found at the end of 10 days. As the former periods are too long for maximum ammonification, the data presented are probably of little value, although it will be noticed that there is but little change in the relative positions of the different soils throughout the 30 days.

Purified egg elbumen, cotton seed meal and tankages, besides the materials herein employed, have in the past been compared with dried blood as to ammonification in Hawaiian soils by the author. The latter, however, has been found to give results slightly more in accord with field conditions, and it is now used almost entirely in work of this character.

From the data presented it is evident that ammonification is not, as a rule, suitable in differentiating between good and poor Hawaiian soils, although it may show differences between *very poor* and *very good soils*. Similar conclusions were reached by Kelley (12), also working with Hawaiian soils. He found that, as a rule, good and poor soils alike supported vigorous ammonification, while nitrification was a variable

quantity depending more or less upon aeration. This work also bears out the conclusion of Gainey (8), working on Kansas soils, who says, "A study of the data here represented, secured from widely different localities, soil types, and variations in productivity, convinces anyone of the absence of any correlation between yield and ammonia nitrogen content." On the other hand, Brown (3; 4) secures ammonification results in complete agreement with crop yields. He writes, "It would seem, therefore, that there must be some close relationship between the ammonifying power of soils and their crop production."

*The Nitration Results.* Kelley (12) has recently shown that, for nitrification tests, smaller quantities of nitrogen carrying materials are to be preferred to the older methods where the equivalent of from one to two per cent. of dried blood was used. A better differentiation between both fertilizers and soils is possible where amounts of organic materials somewhat in accord with actual field practice are employed. For these reasons 30 milligrams of nitrogen from each of the three organics were employed per culture in these nitrification tests. The actual amounts of each fertilizer required to furnish 30 mgms. of nitrogen were:

A. Dried blood (13.5 % N.) = 0.222 gms.
B. Alfalfa meal ( 3.0 % N.) = 1.000 "
C. Fish scrap ( 7.73% N.) = 0.388 "

The beaker method employing 100 grams of soil per culture was used throughout. The incubation temperature was 28°C. At the end of each of the 3 incubation periods (10, 20 and 30 days) one culture from each series was removed and analyzed for nitrates by the modified phenol-disulphonic-acid method (16). All of the results obtained appear below in Table III.

TABLE 3.

THE NITRIFICATION RESULTS.

| Lab. No. | 10-day Incubation Period | | 20-day Incubation Period | | 30-day Incubation Period | |
|---|---|---|---|---|---|---|
| | Mgs. added N. Nitrified | % added N. Nitrified | Mgs. added N. Nitrified | % added N. Nitrified | Mgs. added N. Nitrified | % added N. Nitrified |
| 1A .... | 4.7 | 15.7 | 15.2 | 50.6 | 15.2 | 50.6 |
| 1B .... | 3.8 | 12.7 | 9.0 | 30.0 | 9.0 | 30.0 |
| 1C .... | 4.4 | 14.7 | ... | ... | 12.0 | 40.0 |
| 2A .... | 2.5 | 8.3 | 13.6 | 45.3 | 20.8 | 69.3 |
| 2B .... | 1.8 | 6.0 | 8.0 | 26.7 | 15.2 | 50.6 |
| 3A .... | 3.2 | 10.7 | 12.0 | 40.0 | 20.0 | 66.7 |
| 3B .... | 1.8 | 6.0 | ... | ... | 12.0 | 40.0 |
| 4A .... | 4.7 | 15.7 | 14.0 | 46.7 | 18.0 | 60.0 |
| 4B .... | 4.7 | 15.7 | 11.0 | 36.7 | 12.8 | 42.7 |
| 5A .... | 6.0 | 20.0 | 6.0 | 20.0 | 4.0 | 13.3 |
| 5B .... | 3.8 | 12.7 | 5.6 | 18.7 | 7.2 | 24.0 |
| 5C .... | 9.0 | 30.0 | 9.4 | 31.3 | 5.0 | 16.7 |
| 6A .... | 1.8 | 6.0 | 9.0 | 30.0 | 17.2 | 57.3 |
| 6B .... | 0.9 | 3.0 | ... | ... | 9.6 | 32.0 |
| 7A .... | 4.0 | 13.3 | 12.0 | 40.0 | 13.6 | 45.3 |
| 8A .... | 4.5 | 15.0 | 16.0 | 53.3 | 16.8 | 56.0 |
| 8B .... | 6.0 | 20.0 | ... | ... | 10.0 | 33.3 |
| 9A .... | 7.0 | 23.3 | 4.0 | 13.3 | 4.0 | 13.3 |
| 9B .... | 4.4 | 14.7 | 5.6 | 18.7 | 4.5 | 15.0 |

It is usually found that the optimum incubation period for nitrification in soil cultures under laboratory conditions is from 4 to 5 weeks. The three periods, 10, 20 and 30 days, were here chosen in order that the rates of nitrification, as well as the absolute amounts of nitrate formed during one month, might be ascertained. With the exception of the poor soils, Nos. 5 and 9, it will be noted that there was a steadily increased production of nitrate nitrogen from the 10th to the 30th day in almost all cases. Especially is this noticed with the best soils under examination, *i.e.,* Nos. 2, 3, 4 and 8. With soils 5 and 9 there was a decrease after the first 10 day period in many cases. This was possibly due to denitrification in some cases, while in others the rapid evolution of ammonia occurring at first might have had a tendency to correct existing acidity, thus initially rendering conditions more nearly suitable for nitrification.

Let us now arrange the soils in their order of nitrate production (as shown at the end of the 30 day incubation period where dried blood was used). Beginning with the best, the soils

fall in the following sequence: Nos. 2, 3, 4, 6, 8, 1, and 7, while 5 and 9 happen to be the same, and are the lowest. The first four or five soils thus listed are all of high productivity, and, as Table III shows, differ but little in the large percentages of added nitrogen nitrified, while Nos. 5, 9 and 7 are the lowest nitrifiers, and we know them to be the poorest soils.

Where alfalfa meal was used in place of dried blood (but supplying exactly the same amount of nitrogen, 30 mgms.), the soils group themselves in the following order: Nos. 2, 7, 4, 3, 8, 6, 1, 5, and 9. Soil No. 2 still heads the list, while Nos. 5 and 9 remain the poorest. The only change of note is in the case of soil No. 7, which here occupies second place, while with dried blood it came later. Soil No. 7 is not a productive soil and why here it should occupy a post so near the front cannot be explained unless it was accidentally contaminated, or unless the causes of its infertility are other than low nitrifying efficiency. That the latter is in part true is known to the writer who made a careful study of these two Honomu soils (Nos. 4 and 7) over a year ago, and submitted his findings at that time to the manager of the Honomu Sugar Company. The results of the chemical work performed upon these two soils at that time were as follows:

| Soil | Citrate Soluble | | | Total N. | Lime Requirement—Tons per Acre Foot (Veitch) |
|---|---|---|---|---|---|
| | $CaO$ | $P_2O_5$ | $K_2O$ | | |
| No. 1*...... | 0.083% | 0.0076% | 0.0118% | 0.53% | 7.5 |
| No. 2 ...... | .054 | .0046 | .0087 | .34 | 12.2 |

* Nos. 1 and 2 are the same soils as Nos. 4 and 7 in this present paper.

From this work we see that soil No. 7 is in all respects a poorer soil than No. 4. These two samples were taken by our assistant agriculturist, Mr. W. P. Alexander, on July 9, 1917, and were described by him as follows:

"Sample No. 1. Below the ditch is an area which has grown very good cane. It is in a pocket, i. e., there is drainage from two slopes. It was the former site of a Hawaiian kuleana. The soil is deep. The sample was taken from three separate holes dug 1 foot deep. A bag was laid in the bottom of the hole and a slice of the side of the hole taken with a spade. This soil was collected on the bag. The three separate 'slices' of soil were mixed, and constitute the sample.

"Sample No. 2. Above the ditch is an area which produced poor cane. It has grown vegetables in the past. The soil is shallow, as it is more like a ridge where this area is located. The sample was secured from three separate holes, as above described."

From an examination of the data as given in Table III it is evident that the nitrification figures, where dried blood is used and an incubation period of 30 days is employed, are a very good comparative measure of the crop producing powers of the various soils under discussion. It may be stated here that the writer has examined a large number of Island soils for nitrification efficiency, using both dried blood and ammonium sulfate as sources of nitrogen, and almost invariably the figures secured are in accord with the known productivity of the soils so tested. Dried blood usually gives more comprehensive results than ammonium sulfate, or, in fact, than any of the other materials tried.

The findings of the writer, as here stated, are in accord with results secured by several investigators on the mainland. Gainey (8), working with Kansas soils, writes: "As pointed out before there is evidently a correlation between nitrification and yield, but not between any other two factors under consideration." Also, "We believe, therefore, that while there is usually a correlation between nitrifying power and productivity, it does not imply that the processes of nitrification are responsible for yield or that yields on non-fertile soils are limited by the process of nitrification. As to whether high nitrifying powers are the result of high fertility or that both are the result of common factors, there are very few data to indicate. Since it is not impossible that both factors depend upon available plant-food, we would call attention to the work of Lipman (13) who has detected a relation between yields and certain available inorganic elements, also to the work of Fraps (7), who has detected a relation between nitrogen content of soils and their nitrifying powers." I may state here that there is, in Hawaiian soils, little correlation between nitrogen content and nitrification, doubtless due, in large part, to varying degrees of soil acidity.

Brown (3; 4) of Iowa, Given (9) of Pennsylvania, and Lipman (13) of California, have all been able to show a direct relationship between nitrification and crop production.

*Total Nitrogen rendered water soluble.* These tests were set up in exactly the same way as were the nitrification cultures—100 grams of soil in tumblers plus 30 mgms. of the different forms of organic nitrogen. The temperature and periods of incubation were also the same. At the end of each period one culture of each series was removed and, with 400 c.c of nitrogen-free distilled water, washed into a quart Mason jar. The jars were shaken for one hour in a shaking machine, then allowed to stand over night, when practically all of the soil had

settled out leaving the supernatant liquid slightly cloudy. The latter was then carefully and completely siphoned off, leaving the moist soil in the bottom of the jars. The liquids were clarified by passing them through Pasteur Chamberland clay filters under pressure. The first 75 c.c. was discarded. Another 400 c.c. of distilled water was now added to the soils in the jars and the same process repeated. Exactly 200 c.c. of each first clear filtrate was mixed with exactly 200 c.c. of the second extraction of the same soil (which represented 50 grams of the soil culture). Ten c.c. of concentrated sulfuric acid was then added to each solution and the whole reduced to a bulk of about 100 c.c. on the water bath. When cool, each solution was transferred to a Kjeldahl flask, about 8 grams of iron (reduced by hydrogen) was added, and the whole allowed to stand over night to reduce the nitrates present (Ulsch's (2, p. 10) modified method). Most of the water was then carefully boiled off, 30 c.c. more of strong sulfuric acid was added, together with about 10 grams of salt mixture (10 parts $K_2SO_4$, 1 part $FeSO_4$ and ½ part $CuSO_4$) (10), and the whole digested two hours to obtain any soluble organic nitrogen which might have been present. As color was noted in several of the original solutions, it indicated the presence of soluble organic compounds. The digestions were then neutralized and distilled as in the usual Kjeldahl determination for total nitrogen.

That certain soluble forms of nitrogen (ammonium salts, amido-acids, amines, etc.) are quite strongly absorbed by soils and are retained at least in part against washing with pure water, is an established fact. Hence the moist soils, from whence the supernatant liquids had been withdrawn, were transferred to copper flasks and distilled with magnesium oxide. The sum of these two portions, minus the blanks on the soils examined, represents probably very closely the total amounts of water soluble nitrogen formed by the soil flora from the added insoluble organic materials.

The results as secured by this method appear in Table IV. The first columns under each incubation period show the milligrams of nitrogen (blanks subtracted) which were secured in the water extracts; the second columns, the milligrams found in the residual soils after the extractions (blanks subtracted); the third columns, the sum of these two; and in the last columns under each time period appear the percentages of added organic nitrogen rendered soluble.

TABLE 4.

THE TOTAL NITROGEN RENDERED WATER-SOLUBLE.

| Soil No. | 10-day Incubation Period | | | | 20-day Incubation Period | | | | 30-day Incubation Period | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mgms. N from $H_2O$ Solutions | Mgms. N. from Soils | Total Mgms. N. Recovered | % N. Rendered $H_2O$ Soluble | Mgms. N from $H_2O$ Solutions | Mgms. N. from Soils | Total Mgms. N. Recovered | % N. Rendered $H_2O$ Soluble | Mgms. N. from $H_2O$ Solutions | Mgms. N. from Soils | Total Mgms. N. Recovered | % N. Rendered $H_2O$ Soluble |
| 1A ...... | 11.9 | 8.4 | 20.3 | 67.7 | 14.7 | 3.6 | 18.3 | 61.0 | 14.0 | 2.5 | 16.5 | 55.0 |
| 1B ...... | 8.4 | 2.2 | 10.6 | 35.3 | 11.2 | 3.4 | 14.6 | 48.7 | 10.5 | 2.5 | 13.0 | 43.3 |
| 1C ...... | 11.9 | 6.9 | 18.8 | 62.7 | ... | ... | ... | ... | 12.6 | 2.2 | 14.8 | 49.3 |
| 2A ...... | 9.1 | 17.9 | 27.0 | 90.0 | 15.4 | 14.0 | 29.4 | 98.0 | 19.8 | 1.4 | 21.2 | 70.7 |
| 2B ...... | 7.7 | 13.4 | 21.1 | 70.3 | 12.6 | 9.5 | 22.1 | 73.7 | 15.4 | 3.3 | 18.7 | 62.3 |
| 3A ...... | 11.9 | 9.8 | 21.7 | 72.3 | 16.8 | 7.6 | 24.4 | 81.3 | 16.8 | 2.8 | 19.6 | 65.3 |
| 3B ...... | 8.4 | 8.4 | 16.8 | 56.0 | ... | ... | ... | ... | 13.3 | 4.7 | 18.0 | 60.0 |
| 4A ...... | 12.6 | 7.5 | 20.1 | 67.0 | 17.5 | 6.4 | 23.9 | 79.7 | 14.7 | 2.5 | 17.2 | 57.3 |
| 4B ...... | 9.8 | 3.9 | 13.7 | 45.7 | 14.0 | 4.5 | 18.5 | 61.7 | 12.6 | 3.6 | 16.2 | 54.0 |
| 5A ...... | 7.7 | 0.5 | 8.2 | 27.3 | 8 4 | 1.9 | 10.3 | 34.3 | 4.2 | 1.4 | 5.6 | 18.7 |
| 5B ...... | 6.3 | 0.5 | 6.8 | 22.7 | 9.1 | 1.6 | 10.7 | 35.7 | 10.5 | 2.5 | 13.0 | 43.3 |
| 5C ...... | 9.1 | 1.2 | 10.3 | 34.3 | 11.9 | 1.1 | 13.0 | 43.3 | 9.1 | 1.1 | 10.2 | 34.0 |
| 6A ...... | 9.8 | 14.5 | 24.3 | 81.0 | 16.1 | 10.9 | 27.0 | 90.0 | 16.5 | 1.9 | 18.4 | 61.3 |
| 6B ...... | 7.7 | 6.4 | 14.1 | 47.0 | ... | ... | ... | ... | 14.0 | 3.6 | 17.6 | 58.7 |
| 7A ...... | 9.1 | 6.1 | 15.2 | 50.7 | 14.7 | 7.6 | 22.3 | 74.3 | 10.5 | 1.9 | 12.4 | 41.3 |
| 8A ...... | 14.7 | 15.0 | 29.7 | 99.0 | 16.1 | 6.7 | 22.8 | 76.0 | 18.2 | 3.3 | 21.5 | 71.7 |
| 8B ...... | 9.1 | 5.6 | 14.7 | 49.0 | ... | ... | ... | ... | 13.3 | 3.6 | 16.9 | 56.3 |
| 9A ...... | 11.2 | 10.9 | 22.1 | 73.7 | 16.1 | 15.0 | 31.1 | 103.7 | 18.2 | 12.0 | 30.2 | 100.7 |
| 9B ...... | 12.6 | 10.0 | 22.6 | 75.3 | 17.5 | 12.6 | 30.1 | 100.3 | 14.0 | 16.0 | 30.0 | 100.0 |

A perusal of Table IV. shows that the highest percentages of organic nitrogen rendered water soluble were secured at the end of the 20 day incubation period. Under the conditions of this test we measure both the ammonia nitrogen and the nitrate nitrogen produced, as well as the simpler protein compounds and decomposition products which have been rendered water soluble by the soil bacteria and fungi. That there is a gradual increase in nitrate nitrogen from the first period to the last, and that the reverse is shown for ammonia production, is brought out by comparing the nitrogen in the water soluble portion (which doubtless contains practically all of the nitrate) with that recovered by distilling the residual soils with magnesia (which, due to absorption, probably carries a large part of the ammonia). This fact is possibly better shown by comparing the "milligrams of added nitrogen nitrified" in Table III with the "total milligrams of nitrogen recovered" from the soils as shown in Table IV, for both sets of cultures were similar in the essential details, and should be fairly comparable.

It is to be regretted that cultures were not analyzed at the 20 day period for soils 1C, 3B, 6B and 8B. This was due to lack of soil. However, where dried blood was employed as the source of nitrogen (the "A" cultures), a complete series at the 20 day incubation period is before us for discussion. Let us consider the relative percentages of added blood nitrogen rendered soluble by the several soils. Soil No. 9 heads the list with all of the added nitrogen rendered soluble. It will be recalled that this is one of the poorest soils under discussion, also that its ammonification coefficient was similarly high. The table shows us that a large percentage of this soluble nitrogen is here present as ammonia. The soils occur in the following order, depending on their abilities to render blood nitrogen soluble: Nos. 9, 2, 6, 3, 4, 8, 7, 1 and 5. It is evident that this order does not correspond with the known fertility of these soils although, with the exception of Nos. 9 and 1, there is a general tendency for the better soils to appear first.

In so far as data are available for the alfalfa meal series (the "B" cultures), the soils appear in exactly the same order as in the blood series, *i.e.*, Nos. 9, 2, 4, 1, and 5.

From a careful study of Table IV it is evident that the amount of organic nitrogen rendered water soluble by a soil's flora is hardly a criterion whereby we may judge of its inherent capacity to produce crops, or whereby comparative fertilities may be differentiated, except in a very general way.

*Nitrogen Fixation.*. Due to lack of soil, it was impossible to determine the nitrogen fixing powers of these soils by the beaker,

or soil culture, method. Mannite solutions (5) were therefore made up carrying one gram of mannite per 100 c.c. Wide-mouthed Erlenmeyer flasks of 500 c.c. capacity, each receiving 100 c.c. of solution, were sterilized and, when cool, innoculated with 1 gram each of the soils under examination. These cultures were incubated 3 weeks at 28°C., after which total nitrogen determinations were made. These figures (minus the amount of nitrogen introduced with each gram of soil used as an inoculum) together with the appearance of the cultures, appear in Table V.

TABLE 5.

THE NITROGEN FIXATION RESULTS.

| Soil No. | Mgms. N. Fixed per Culture (per 1 Gm. Mannite) | Presence of Azotobacter |
|---|---|---|
| 1 | 5.60 | ? |
| 2 | 11.20 | + |
| 3 | 6.44 | + |
| 4 | 7.00 | + |
| 5 | 2.80 | — |
| 6 | 7.28 | + |
| 7 | 3.92 | ? |
| 8 | 10.64 | + |
| 9 | 3.60 | — |

Let us briefly consider the data as here given. The three poorest soils certainly fix the least nitrogen, while soils Nos. 2 and 8, which are certainly among the best soils under discussion, fix the most. Azotobacter forms were entirely absent from cultures 5 and 9, while their presence in 7 was doubtful. All of the other soils, except possibly No. 1, gave cultures showing good Azotobacter surface membranes. These nine soils fall naturally into three classes depending upon their nitrogen fixing abilities. The first or best is comprised of soils 2 and 8, which fix about 11 milligrams of nitrogen each where one gram of mannite is supplied as the source of energy. To the second class belong soils 6, 4, 3, and 1. These are able to fix about 6 or 7 milligrams under the same conditions. The third or poorest class composed of soils 5, 7, and 9, are able to secure less than 4 milligrams of atmospheric nitrogen under the conditions imposed.

Arranging the soils in the order of their abilities to fix free nitrogen in mannite solution cultures we have: Nos. 2, 8, 6, 4, 3, 1, 7, 9 and 5. Where nitrate production (nitrification) was the measure of comparative fertility employed, it will be recalled that the following order was shown: Nos. 2, 3, 4, 6,

8, 1, 7, 5, and 9, which, considering the slight differences obtaining in both cases between the results secured with soils 6, 4, 3, and 1, is certainly a remarkably close agreement. Brown (3) of Iowa has also shown a very complete agreement between nitrogen fixation and nitrification.

## SUMMARY.

The object of this work, as stated in the title, was to ascertain whether or no it is possible to predict, with any degree of accuracy, the crop-producing powers of Hawaiian soils, or rather their relative crop producing powers, from microbiological data, *i. e.,* ammonification, nitrification, nitrogen fixation, etc., and if so, which is the best criterion to use in routine, comparative tests.

Nine Hawaiian surface soils, all of which had been under sugar cane cultivation for many years, were chosen for this investigation. Two or three of them were of exceptional fertility, three were capable of yielding good average crops, while three produced poor crops of cane even after fair fertilizer applications.

These soils were brought to the laboratory, carefully sifted through a 5 m.m. sieve after being air dried in the shade, and the following tests made upon them: ammonification, nitrification, total supplied organic nitrogen rendered water soluble and nitrogen fixation. Three incubation periods were used, vs., 10, 20 and 30 days, while three different organic forms of nitrogen (dried blood, fine alfalfa meal and fish scrap) were employed. The ordinary precautions against contamination were taken.

The methods used, together with all of the results obtained, are discussed.

The following conclusions seem justified:

1. Ammonification tests are not suitable to differentiate between the fertilities of average Hawaiian soils, although they will often show differences between *very poor* and *very good* soils.

2. The abilities of soils to render organic nitrogen (of blood or alfalfa) water soluble are of no value as measures of their crop producing powers.

3. Nitrification (soil culture method) is by far the most accurate biological soil test yet perfected for predicting probable fertility. In fact, it is probably the best single test of any description yet developed for ascertaining the comparative crop-producing powers of arable soils. At least, this holds for Hawaiian soils, and it may be added that the writer has tested scores of Island soils by the method for nitrification as given

herein, and in only a very few instances have the nitrification coefficients been at variance with the known fertility of the fields from whence the samples were drawn. Of course there are exceptions, and it must not be inferred that nitrification tests are able to take the place of carefully conducted chemical or vegetation experiments. Active nitrification may not be the *cause* of high fertility, yet those conditions which tend to promote rapid nitrification are very evidently identical with those which tend to give us enhanced crop yields. Furthermore, although nitrification tests may be a means of differentiating between good and poor soils, they do not tells us the *causes* of the differences noted, nor do they show us exactly how to *improve conditions* in soils of low productivity. Chemical, physical and plant physiological experiments alone are able to give us this information. A discussion of these phases of soil work falls beyond the limits of this paper.

4. There was a remarkable correlation between the amounts of nitrogen fixed in mannite solution cultures and the known fertilities of the soils studied. There was little difference in the comparative rating of the soils depending upon whether nitrification or nitrogen fixation tests were used as the criteria of fertility. Azotobacter species are seldom present in Hawaiian soils of low productivity; the more fertile soils, however, carry several species (6), and in so far as fixation is concerned, compare favorably with mainland soils of similar crop producing powers.

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# NEMATODE GALLWORMS OR EELWORMS.†

By A. L. Lovett

Considerable interest is manifest concerning the eelworms or nematode gallworms, due largely to the recent agitation concerning their injury to potatoes. Because of the presence of these worms in neighboring states, it seems advisable to warn our growers of the possibilities of the pest, and to urge them to use every precaution to prevent its introduction into their fields.

## WHAT NEMATODES ARE.

The nematodes or nematode worms are not insects. They belong to the round worms or Vermes, and are much lower in the animal scale than are insects. Popular names for nematodes include "threadworms," "eelworms," "flukes," etc. Most forms are of no economic importance, living principally on decayed matter. A number of forms are parasitic for at least a portion of their life on animals, and a few forms are parasitic on plants.

## HOST PLANTS.

The list of plants known to be attacked by this nematode includes over 450 names. Practically all garden and truck crops are included as hosts; many of the field crops and a great variety of fruit, shade and ornamental trees, shrubs and plants are also attacked. Mr. Schofield* mentions the following list of plants as readily and seriously attacked: Beets, carrots, celery, cucumbers, eggplant, lettuce, muskmelons, watermelons, clover, cowpeas, rape, soy beans, catalpa, cherry, elm and peach.

## DISTRIBUTION.

The nematode gallworm is fairly well distributed over most of the known world. Bessey writes that,

"It has been present in the United States for many years, and has caused losses whose extent cannot be calculated. Although more abundant in the South, it is present, at least sporadically, in all but the most northern and northwestern states, as an out-of-door pest, and is everywhere distributed in greenhouses."

† Oregon Experiment Station Annual Report 1915-1917.
* Schofield, C. S., U. S. Dept. Agr., Bur. Plant Ind., 1912, Cir. 91.

The irrigated potato districts of Nevada are a concrete example of a locality which may regard the pest as a real menace. The pest is present in practically all the region east of the Mississippi River. It is present in parts of California and in scattered sections of the Middle West.

### MEANS OF DISTRIBUTION.

The nematode gallworm may be distributed to new localities in the soil from infested fields, or on the roots of any one of the many plants which it infests.

Nursery stock is one of the most common means of distribution. All shipments of trees, shrubs, plants, etc., of whatsoever nature, should be examined carefully for galls, knots, or irregular growths on the roots. Any such unnatural growth should be viewed with suspicion, and every precaution taken to prevent unwittingly introducing into the soil a pest capable of untold injury.

Potatoes afford another ready means of distribution. Seed potatoes in particular should receive the most rigid examination. Under no circumstances should they be purchased from a locality known to be infested with the eelworm disease.

### SYMPTOMS AND NATURE OF INJURY.

*In the Field.* Nematode gallworms, *Heterodera radicicola,* attack the plant under ground, causing a trouble known as root knot, root gall, big root, etc. These irregular enlargements occur at all points on the main and lateral roots, and are an integral part of the root itself. The gall is made up of abnormal cells which do not function normally. An affected plant, therefore, is robbed of its normal food supply.

The effect of this condition becomes apparent in the lighter crop or in the death of the plant.

The earlier symptoms of nematode injury, apparent above ground, are just as applicable to those of injury by insects or fungi. Where the cause is unknown, however, and these symptoms occur, nematodes may reasonably be considered as a possible cause. An examination of the roots for galls is then advisable. In the earlier symptoms of the disease, a dwarfing of the plant is usually apparent. The plant wilts in the heat of the day, and appears slightly off in color.

*On Potatoes.* The eelworm of potatoes is a very serious trouble. The most notable example of what the pest can do

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Bessey, E. A., U. S. Dept. Agr., Bur Plant Ind., 1911, Bul. 217, p. 7.

is found in some of the irrigated potato districts of Nevada. Previous to the introduction of the nematode gallworm, potatoes were one of their most profitable crops. The potatoes produced here were of a superior quality, and usually commanded a higher price on the market than those from other sections. California afforded the principal market for these potatoes. When the presence of the eelworm disease was noted, California quaran-


The roots of a tomato plant affected by nematode galls.

tined against the potatoes from this section of Nevada, and turned back several cars containing infested tubers.

The skin of the infested potato is usually roughened and cracked, and has irregular pimples over the surface. These pimples or nodules are grayish or brownish in color. They are often more or less depressed in the center and surrounded by a slight furrow. In the earlier stages of the disease, the potato may be full and firm, but as the disease ad-

vances, the tuber shrivels and becomes more or less soft. Badly diseased potatoes shrivel to one-half the natural size, are soft, lack nutrition, and are unfit for human food.

Occasionally an infested potato shows no symptoms on the surface. Upon cutting into the potato, rings of darkened tissue appear just below the skin, extending from 1/16 to 1/4 inch into the flesh. These brownish rings are corky in texture, with a central whitish core. This core contains the nematode gallworms in all stages of development.

*In the Greenhouse.* As stated previously, the nematode gallworm is distributed practically everywhere in greenhouses. A serious attack of nematodes occurred in a frame of tomato plants in the College greenhouse the past spring. Unfortunately the pressure of other matters prevented our giving the matter the attention necessary and no determination was made of the species. It is assumed, however, that it is this species.

The symptoms of attack are more apparent above ground in the case of greenhouse plants than with outdoor plants. There is usually more or less forcing of the plants here, and any checking of the thrift of the plant quickly becomes apparent. The first symptoms of injury above ground are a checking in the growth; the plants become a lighter green in color, and are in poor thrift. Later, in the case of tomato plants, deadened areas appear between the ribs of the leaf adjacent to the midrib. The leaves curl, thicken up, and become twisted and off color. The plant eventually wilts down and dies.

The roots are attacked in the same manner as under field conditions. An infested plant will show the abnormal galls and knots.

## CONTROL MEASURES.

*In the Field.* A great number of materials are suggested as of some value against the nematode gallworms in the field. At best the control methods to be employed here entail considerable time and expense and are only in a measure satisfactory. Keeping the soil free of vegetation for a period of two years, and planting non-susceptible crops are two methods which seem most likely to free the soil of the pest. Either of these methods is expensive. This serves to emphasize the necessity of keeping the pest out of our soil if at all possible.

*In the Greenhouse.* During late April, Professor Bouquet, of the Horticultural division, reported serious nematode injury to his tomato plants in the greenhouse. The plants were of a very fair size, there being already a considerable setting of fruit.

The infested plants occupied the west half of one section of the greenhouse. There were forty-eight plants, twelve in each of four rows. The plants were trained to a single runner, and this was supported upright by a strong twine attached to the roof. At the time when our attention was called to the trouble, many of the plants were already drooping badly and a few of them were dead.

On April 25, 1914, I treated the frame of tomatoes as follows: The south half of the frame was treated with ammonia water[27], 1% (?) solution. The north half of the frame was treated with formaldehyde, 1% (?) solution. The 1% solution in each case is figured on the basis of 100% for the commercial material. We obtained the commercial 40% formaldehyde and diluted one part of formaldehyde to 99 parts of water. The concentrated ammonia was diluted in the same way, one part to 99 parts of water. This was arrived at only approximately, however, as I used four ounces of the solution to three gallons of water, or 4 to 384.

One gallon of the solution was applied to each plant. In the checks, one gallon of water was used. A shallow circular trench was formed about each plant; the solution poured into this trench and allowed to soak into the roots.


Tomato plant suffering from nematode injury.

On May 12, the portion of the frame treated with formaldehyde and the checks were removed. The plants treated with the ammonia water solution seemed entirely over the effects of the nematode injury; were growing nicely, and producing fruit.

*Steam Sterilization* is highly recommended, and where conditions permit the installation of the necessary apparatus, this treatment is advocated. Bessey* gives a summary of the treatment as follows:

"At the bottom of the bench or bed are laid either iron pipes perforated with 1/16 inch holes every few inches or drain tiles. Live steam is passed into these and escaping from the holes of the iron pipes or between the ends of adjacent tiles, heats the soil to such a degree that all animals and most plants (except, of course, bacterial spores) are killed. The pipes must be placed at intervals short enough to permit the spaces between the rows of piping to be thoroughly permeated by the steam. This distance varies with the soil, but 12 inches is close enough for all general purposes, and even 2 feet is not too far in deep beds if the sterilization is kept up long enough. The bed should be covered with straw, boards, sacking, or something of the kind, to permit the upper layer of soil to become heated through. The pipes or tiles in the soil should be arranged lengthwise in the beds, with the steam inlet in a crosspiece of piping running across the bed, from which the longitudinal rows take their origin. A similar crosspiece at the other end may be used, but is not absolutely necessary. There should be no open ends of pipes or tiles; otherwise all the steam will escape out of these and not through the cracks or small holes. Depending upon the pressure of steam used, the time necessary for sterilization will vary from half an hour to even two hours when the pressure is poor.

A method often recommended to determine whether the steam has passed long enough, and one that has considerable merit, is to bury raw potatoes at the surface of the soil underneath the covering of straw, boards, or sacking. When all these potatoes are found to be cooked the steam can be safely turned off. Stone and Smith recommend the use of a special boiler so that steam at fairly high pressure can be used, but under 40 pounds per square inch, preferably more. Even 80 to 100 pounds pressure is not too high if obtainable, as it shortens the time necessary and also prevents the soil from becoming as wet as with lower pressure.

"Not only are all nematodes killed by this treatment, but also

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* Bessey, E. A., U. S. Dept. Agr., Bur. Plant Ind., 1911, Bul. 217, p. 44.

all insects and other noxious animals, as well as all fungi and their spores. Many bacteria are killed, too, but not all of their spores, the survival of the latter being desirable in view of what we know of the value of soil bacteria.

"This method has some disadvantages. Thus, it cannot be used for beds occupied by living plants. Furthermore, care must be taken on the one hand not to leave the soil soggy and on the other not to dry it out too much. The latter is, however, a much less serious matter than the former."

*Fresh Soil.* In a great many cases, where the soil in greenhouse frames is infested with nematodes, the most simple practice is to employ fresh soil each year. The old soil should be allowed to dry out thoroughly for some weeks before removing it. Care should be taken to place it where there is no danger of spreading the trouble. A hard roadway is good providing there is no danger of the soil being tracked onto cultivated fields. The frames should be gone over with whitewash, freshly made from good live quicklime.

*Formaldehyde.*. Where satisfactory soil is difficult to obtain, the infested soil may be treated with formaldehyde. For best results, this treatment must be applied when the frames are free of plants. In the greenhouse at the College a solution of two parts of commercial formaldehyde to 100 parts of water was used. Where the frames are fairly shallow, 1½ gallons of the solution to every square yard of soil surface is sufficient. The soil should be thoroughly stirred after treatment to allow all parts to become thoroughly disinfected. The excess of formalin should be allowed time to escape before new plants are placed in the soil.

*Trap Plants.* In some cases trap plants might be employed to advantage. In soil believed to be infested with nematodes where sterilization is not practical, a few hills of beets and lettuce, for example, might be planted among the tomatoes, cucumbers, or other plantings. After once the initial infestation has taken place, the trap plants should be removed and destroyed, new ones being added.

## LIFE HISTORY AND DESCRIPTION.

When one of these nematode galls is broken open and the interior carefully examined, minute, glistening white, pearl-like cysts are observed here and there in the tissue. These bodies are about one-half as large in diameter as the head of a pin. They are the mature female nematodes and the cause of the formation of the galls.

The nematode gallworms occur in the soil as minute, thread-like creatures less than 1/25 inch long. When plants suitable for their attack are present, the worms seek the growing tip of a rootlet and batter their way to the interior by means of a spear-like organ situated in the mouth. When once fixed in position, they become inactive and commence to feed and grow. The growth is mainly in thickness, and only slight in length. The larva slowly assumes a spindle shape.

After a period of about fifteen days, the form of the two sexes commences to differ. The female now assumes a flask or pear shape and is similar in appearance to the cyst observed when a gall is broken open. The male nematode transforms rapidly during this same time, and gradually assumes once more the elongate, work-like form. It soon becomes active and seeks out the female for fertilization, after which it dies. The fertilized female continues to increase in size, and after a few days egg laying begins. A single female will deposit 400 to 500 eggs.

Minute larvae soon emerge from these eggs. The major portion of them tunnel to the exterior of the root, crawl out into the soil and seek new plants for attack. Some of them simply work their way through the plant tissue a short distance and establish themselves in the root near the parent gall.

## SUMMARY.

The nematode gallworm is a very serious pest. It is present in adjacent States and causes untold losses by its work. It attacks the majority of our cultivated plants, stunting their growth, lessening the yield, rendering the crop unsaleable, or killing the plants outright. It may be distributed in soil, or on plant roots. Nursery stock and potatoes particularly should be examined and every precaution taken to avoid planting diseased plants or tubers.

While the results of a single test are not conclusive, the success of the ammonia water treatment in our experiment warrants further trials. Until something as practical and more effective is found for treating growing plants in the frames, greenhouse men are warranted in giving this material a trial. Soil free of plants and liable to infestation by nematodes should be steam sterilized. Where this is not possible, use fresh soil or disinfect with formaldehyde. Trap plants are of some value under certain conditions.

# A NEW CANE DISEASE.

By E. L. Caum.

Fig. 1. A bad infection on the rind.

Recently the attention of the pathologists was called to a peculiar condition appearing in one of the 1915 seedlings of H-109 in the Experiment Station grounds. The rind on a single joint of this cane was dead and dry, giving the joint somewhat the appearance of bamboo (Fig. 1). A closer examination was at once made, and showed that this condition was present to a lesser degree on other canes of this seedling and on other seedlings in the block. The dead areas appeared as irregular patches on the culms and as spots on the sheaths, both conditions often appearing on one stick, but the normal position seems to be on the sheath (Fig. 2). The spots were not found on the leaves at all.

Examination of these spots with a hand-lens disclosed the presence of minute black spots scattered about in the dead area—the fruiting bodies of the causative fungus (Fig. 3). Microscopical examination of these fruiting bodies showed the fungus to belong to the genus *Phyllósticta,* a large group of leaf parasites. There are several hundred species in this genus, and they have been found on the leaves of many kinds of plants, but

only two have been described from sugar cane, *P. Sacchari* having been discovered in Argentina and *P. saccharicola* in the Congo. The fungus found here is neither of these, and is probably a new species, being so described here under the name *Phyllosticta hawaiiensis.*

The fungus appears to be primarily a sheath parasite, attacking the sheath at or near the point of attachment, killing the tissues and causing the formation of characteristic spots. In many cases, however, the fungus does not limit its growth to the sheath but pushes downward onto the rind of the internode below, as in the examples figured.

Fig. 2. Infection on sheath spreading downward onto the rind.

Fig. 4. The ordinary plantation appearance.

This Phyllostica, while it was only recently discovered, appears to be rather widely distributed on Oahu, at least. Immediately after its discovery a survey was made of several plantations on this island, and the fungus was found on all of them. More recently it has been found on one plantation on Maui. It seems to attack all varieties of cane, although with varying degrees of virulence. The block of seedlings in which it was first found was badly infected, there being only four varieties in the sixty-six on which the fungus was not apparent. On the plantations it has been found attacking Lahaina, Big Ribbon, Striped and

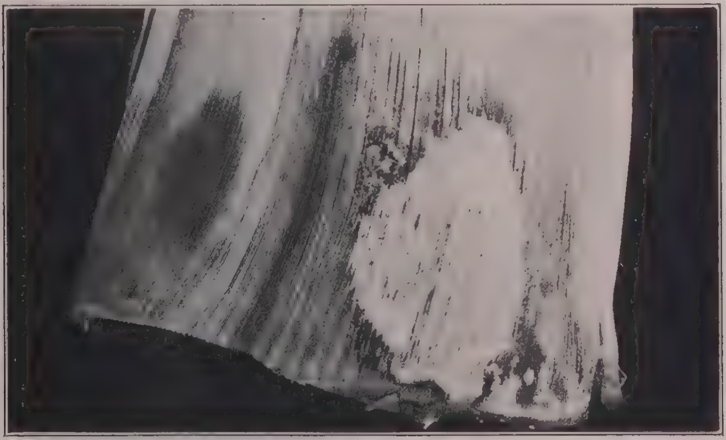


Fig. 3. *Phyllosticta* spot on leaf-sheath, enlarged to show the characteristic black specks.

Yellow Caledonia, Badila, D-1135, H-27, H-109, H-146, H-240, and H-463. The lot of "H-5900" seedlings in which it was first found were by far the worst hit, nothing to compare with them being found on the plantations. (Fig. 4)

This fungus, although it has been noticed just within the last few months, is almost certainly not a new importation. It has very probably been here for years, although escaping our attention by its rarity. Conditions this past year were probably such as to favor its spread and so make it more conspicuous. In fact, a curious coincidence seems to prove its presence here at least twelve years ago. In 1906 a number of colored drawings of cane varieties were made, including native Hawaiian canes and imported varieties which were more or less extensively grown on the plantations. Later several of these drawings,

representing varieties which were no longer grown in Hawaii, were taken from their frames and stored away. In looking over these latter drawings, a short time after the survey of Oahu was made, the writer noticed that one of the pictures, that of Demerara 115, showed a very characteristic Phyllosticta spot on the leaf sheath. Apparently the specimen of D-115 from which the drawing was made was infected by the fungus, and the artist included this spot in his picture. Of course, it is impossible to say with certainty that the spot on that sheath was caused by the Phyllosticta, but the color, shape and position are very similar to the color, shape and position of undoubted Phyllosticta spots found on the plantations. This strange coincidence of the particular piece of cane selected as the model for the drawing having been infected by this fungus seems to show that it has really been in the Islands for a long time. And it is a strange coincidence, for even now the fungus is rare. It is of rather wide distribution, it is true, but it is not at all common in any one place, and in view of these facts it does not seem likely that it will become a serious malady. A technical diagnosis follows:

## *PHYLLOSTICTA HAWAIIENSIS* n. sp.


Fig. 5. Spores of *P. hawaiiensis.*

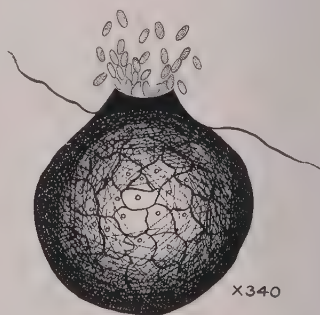



Fig. 6. Pycnidium discharging spores.

Spots conspicuous, dry, straw-colored, sharply defined, sometimes margined with dark red to purple; pycnidia brown, reticulated, at first submerged, later erumpent, scattered in the spots, roughly globose, with one, occasionally two and rarely three slightly papillate ostioles, which are situated in the center of a narrow black area, size ranging from 30 x 30 to 168 x 136


Fig. 7. Pycnidium seen from above.

microns in single-ostioled specimens to 191 x 141 microns in double-ostioled specimens; spores elliptical, minute, 3.2 to 6.5 x 1.3 to 2.8 microns, hyaline, smooth, with two and sometimes three vacuoles. The pycnidia developed in the rind average much smaller than those developed in the sheaths. Parasitic in the sheath and rind of the sugar cane, Saccharum officinarum, in Hawaii.

## THE DEERR EVAPORATOR.*

By Rene P. Piperoux, M. E.

United States and British patents (U. S., 1,287,650, issued December 17, 1918, and British, No. 16,544/17) have recently been granted to Noel Deerr, for a new form of evaporator embodying many novel features.

The evaporator follows the general lines of the modern standard effects, but aims to overcome some of its most troublesome defects. The upper figure accompanying shows one cell of the apparatus in part cross-sectional elevation, while the lower one gives a horizontal section over the upper tube sheet.

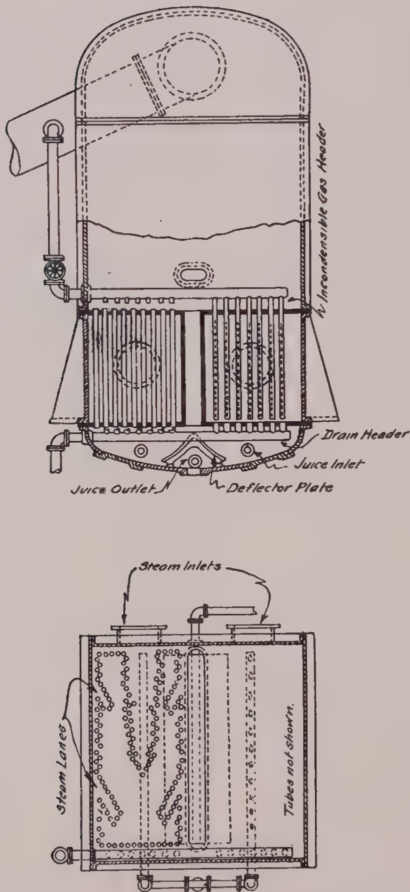
The most striking structural difference between this type and the standard is the square, or rectangular shape. The tube sheets hold the tubes as in the standard type, the portion enclosed between them forming the steam belt, calandria or vapor space.

The incondensible gases are removed by means of the series of vertical perforated pipes at the end of the calandria furthest from the steam inlets.

Exits for the condensed steam are located immediately under the incondensible gas pipes, an inlet under each pipe connecting to a header.

The juice enters through the two perforated headers, one under each half section of the calandria, and goes out through another

* Facts About Sugar, Jan. 11, 1919.




Diagrams showing construction of Deerr evaporator.

*Entry of Juice.*

perforated header running between and parallel to these and situated under the deflector plate.

The circulation is up through the tubes over the sheets into the long rectangular downtake and downward, the descending column being deflected into two currents by the long deflecting plate, which extends through the apparatus and is slightly longer than the downtake. This deflecting plate is provided with perforations large enough to permit escape of the juice into the discharge pipe and yet not so large as to seriously disturb the circulation.

The catch-all is located in the top, semicircle portion of the evaporator, but it is not shown, as it does not form part of Mr. Deerr's claims.

The advantages, as claimed by Mr. Deerr in his patents, are as follows:

(1) Perfect separation of the incondensible gases of the vapor space.

(2) More effective draining of the calandria.

(3) Greater heating surface and capacity per unit of floor space.

(4) Uniform distribution of the liquid entering and leaving the evaporator.

(5) Greater simplicity and cheapness of construction.

(6) The placing of the downtake in the most favorable position for efficient circulation.

As is well known, all steam or vapor contains a certain amount of air and other inert gases in small quantities and condensation of the steam will obviously leave these intact. In an evaporator calandria, or, in fact, in any other condenser type apparatus, if these gases are not removed they accumulate in objectionable quantities collecting on the surface of the tubes, sheets and other portions of the heating surface. Being excellent heat insulators they completely deaden the action of the portions with which they are in contact.

*Gravity Methods Ineffectual.*

It was originally supposed that these gases, being of different specific quantities, would collect either at the bottom or upper

portions of the tube sheets, and could be effectively removed by inserting outlet pipes at these points. Actually this is not the case, as the high velocity of the entering steam keep the gases constantly mixed and all methods based upon specific gravity separation have proved ineffectual in accomplishing their complete removal.

The effect of dead air films on heating surfaces can be seen on an ordinary steam radiator. Its heating effect will be greatly increased by subjecting it to the blast of an electric fan, which will remove the dead film and bring new cold air in contact with the previously heat-insulated surface.

Mr. Deerr's method of removing the incondensible gases is to place numerous small perforated pipes at the *end* of the steam path. By the time the vapors reach this point they have been condensed, leaving the gases alone. The tubes are perforated throughout their length and therefore, whether the gases are light or heavy, they will always be opposite some of the perforations. Further, the steam current tends to drive the gases to the far end.

### *Flooding Prevented.*

The tube sheet is inclined towards the side opposite the steam inlet, the water being drained by the series of openings shown, so that flooding of the calandria is almost impossible. In the present type of standard the same idea is used, but due to the circular shape, the sheets must be made in conical form, which, it must be admitted, is an expensive and difficult task.

In regard to the greater heating surface per square foot of floor space, the advantage is in proportion to the area of a square as compared to that of a circle, which is approximately twenty-five per cent.

The uniform distribution of the liquid, both entering and leaving, is effected by means of the perforated headers before mentioned. The perforation in the inlet pipes divides the stream into small jets, which assist in the circulation. Their location under the tube sheet is chosen with this end in view and also with regard to the fact that since the liquid in the previous cell of the series has been at higher pressure, it tends to flash into steam on entering the new cell, giving up its heat and the steam bubbles formed rising through the tubes.

### *Advantages of Square Section.*

The square section offers advantages over the circular type from the point of view of cheapness of construction. All patterns are flat and all joints at right angles. This enables them to

be easily machined, while the circular segments of the standard types require machining at odd angles. The flat sheets are easier to construct than the truncated cones of the standard sheets. Again, the flat pieces can in a great many cases be made to serve for a number of sizes, which is not the case for cylindrical bodies.

Owing to these features it is demonstrable that for the same capacity and heating surface the Deerr Evaporator will prove cheaper than the standard type.

Objections that might be urged against the square bodies are that they are not so well adapted to resist pressures as the circular type. This is very true, but calculations will show that with the pressures that usually obtain in evaporators the circular shells show absurdly high factors of safety. This is because a shell that would be heavy enough to resist the pressure would be much too thin to give good castings and permit of transportation without breakage and the extra metal is added simply to fulfill these requirements. In the square machine it will be found that the walls, if properly strengthened with ribs, are sufficiently strong to withstand any pressure to which they may be subjected.

*Control of Heat Transfer.*

It will be noted that in the circular evaporator the steam entering from the sides and traveling to the center, the area of the passage is constantly decreasing in a ratio varying as its distance from the center. This is what is wanted, since the steam condenses in its passage and decreases in quantity towards the center, thus tending to keep up high steam velocity which is conducive to good heat transfer.

In the square evaporator the passage is apparently the same throughout, which would result in poor heat transfer at the rear of the machine, since the velocity would drop as the amount of steam decreased. Mr. Deerr overcomes this defect by omitting certain tubes in the sheet, especially those immediately opposite the steam inlet. This forms steam lanes through which the steam rushes to the rear tubes, supplying the deficiency which would otherwise occur. Increasing the number of tubes evidently reduces the cross section of the steam passage, and since the tubes in the rear are more numerous than those in the front the velocity of the steam is maintained.

[R.S.N.]

## THE NITRATE MARKET.

From the American Fertilizer of December 1918, we read as follows from the fertilizer market letter, dated New York, December 18, 1918:

There has been a very quiet market in most items that come under this heading, with buyers not very favorably disposed toward making any contracts for future deliveries. However, owing to the recent changes, the trade is confidentially looking forward to lower prices, as it is generally admitted that the recent quotations have been high. No scarcity of nitrate of soda is now evident, although the commodity is still under a fixed price, but there is little buying interest evident. However, this is not specially so for this product, but may be applied to many of the other items in the fertilizer manufacture. The producers of sulphate of ammonia have eased up slightly in their prices, but this seemingly is having no effect in creating any activity in the market. Fish scrap is firmly maintaining its recent high level and prices for blood tankage are nominally unchanged.

*Dried Blood.* A firm condition continues to prevail in this market, so far as prices are concerned, but buying interest is very quiet, and prices are quotably unchanged.

*Bones.* The consuming demand is not pressing, but in spite of the inactivity prices have not been subject to any decline and remain at the former levels.

*Sulphate of Ammonia.* The consuming trade is taking a fair amount of the product and orders are being booked over next year, but this is only in limited quantities, as there appears to be a disposition on the part of buyers to await a further decline.

*Blood and Tankage.* The situation with respect to these items remains nominally unchanged. Another shipment from South America is due to arrive shortly, but most of this has been sold at the prevailing market prices.

*Nitrate of Soda.* There is seemingly no scarcity at the moment, and orders for the product are being booked right along. The December fixed price is the same as November, $4.42 and $4.55* ex steamer. The following is the statistical position:

PRODUCTION (IN TONS).

| | 1918 | 1917 | 1916 |
|---|---|---|---|
| In November ..................... | 234,500 | 252,700 | 228,700 |
| For eleven months.................. | 2,552,000 | 2,672,400 | 2,609,800 |

* The figures given are the prices per hundred pounds, so we are informed. This would make a price of $88.40 to $91 per ton.

SHIPMENTS FROM THE WEST COAST FOR NOVEMBER (as cabled).

| | 1918 | 1917 | 1916 |
|---|---|---|---|
| To Europe | 36,000 | 60,050 | 119,000 |
| To United States | 179,350 | 150,350 | 65,900 |
| To other parts | 10,300 | 9,300 | 41,800 |

SHIPMENTS FROM JANUARY 1 TO NOVEMBER 30 (as cabled).

| | 1918 | 1917 | 1916 |
|---|---|---|---|
| To Europe | 842,550 | 953,750 | 1,324,150 |
| To United States | 1,754,400 | 1,368,750 | 1,053,700 |
| To other parts | 105,550 | 161,900 | 253,750 |

# WATER TUBE VS. FIRE TUBE.*

## Factors Entering Into the Choice of Boilers for the Sugar Mill.

By RENE P. PIPEROUX, *M. E.*

The two main types of boilers used in cane sugar mills at the present time are the multitubular (also called the return tubular) fire tube type and the sectional water tube type. The former, as is well known, consists of a cylindrical outer shell with end tube sheets into which the three or four inch tubes are expanded. The steam space above the tubes may or may not be connected into a steam drum. The shell in a horizontal position is subjected to the hot fire gases, these being directed to the rear and returning forward through the tubes, after which they enter the smoke flue through a breeching and thence pass to the stack.

* Facts About Sugar, Dec. 28, 1918.

### THE WATER TUBE TYPE.

In the sectional water tube type, tubes containing the water are subjected to the fire. The tubes themselves are connected to headers, the headers in turn going to a drum or drums in the upper part of the boiler setting. In some types the headers are omitted, the tubes being directly expanded into the drums.

Both types of boilers have their advantages and disadvantages, and in selecting the proper type for a particular installation all the factors which will affect the suitability of the boiler should be carefully considered. It is difficult to say which factors should be considered first, as they all play very important parts and each must be considered in conjunction with the others.

### CLASS OF LABOR IMPORTANT

Probably the most important is the class of labor to which will be confided the running of the steam plant. Fire tube boilers are better understood and better handled by the less skilled labor. Due to the comparatively large amount of water in this type of boiler it is sluggish in firing but equally sluggish emptying itself of steam when unusual steam demands are made of it. This of course is an advantage.

The energy of a boiler explosion is directly dependent upon the amount of water released. In a sectional water tube boiler the failure of one of the elements does not cause the failure of the entire boiler, the ruptured part acting as a safety valve for the rest of the system. The failure of a multitubular shell, however, causes the whole contents of the boiler to flash into steam at the suddenly reduced pressure, with generally extremely disastrous results.

Reduction in diameter of a shell submitted to internal pressure greatly increases the strength for the same thickness. The multitubular shell is large and directly subjected to the fire at one portion and only to steam at another. This of course means unequal expansion with its attendant strains, and since the shell is large it must be made thick to withstand the internal pressure, which aggravates the evil.

In sectional water tube types the portion subjected to the fire consists of tubes much more elastic to expansion or contraction than the more rigid shell. That this defect is not altogether absent, however, is shown by the fact that some makers use curved tubes to minimize this by greater elasticity.

## CLEANING AND REPAIR.

Most springing will take place at the joints, tending to leaky tubes. The curved tubes have the disadvantage of being hard to clean and, what is worse, it is impossible to look through them to ascertain the scaling. Water tube boilers are much less accessible for repairs than fire tube boilers. In the former, reaching a tube in the center of a bank may force the removal of other perfectly uninjured tubes to reach a defective one. This is truer in some types than in others. In the fire tube boiler every tube can be reached from the sheets and easy access to the interior of the shell is had by means of manholes.

From this it can be seen that while the multitubular boiler is probably more subject to disastrous explosions than the water tube type, yet the ease of access and simplicity of the former is a thing which is highly desirable in the case of poor labor. The water tender need not be so careful in the case of the multitubular boiler since, due to the large amount of water contained in it, feeding is less frequent.

The next thing to be considered is the pressure to be carried and the size of units. For high pressures and large units the water tube is the only one to be considered. The return tubular, due to its construction, is not suitable for pressures over 150 pounds and preferably not over 125 pounds. The largest units which are desirable are about 250 B. H. P.

The question of pressure is decided by the requirements of the plant. In steam driven factories low pressures (say up to 125 pounds) are the rule. For electric driven plants the requirements of the prime movers for the generating plant are generally high pressure. Some factories have two systems, reserving high pressure water tube boilers for electric plant service and using 100 pound fire tube boilers for heating.

## SIZE OF UNITS.

The size of units is subject to several considerations. The spares installed are, for reasons of interchangeability, made the same as the running units. Now suppose that a plant requires 2,000 B. H. P. If 1,000 B. H. P. water tube units are installed, two units of 1,000 H. P. will be used and a third one as a spare. If 200 H. P. multitubulars are used, ten would be installed and two as spares. In the first case there is 1,000 useless horsepower and in the second case only 400. The useless horsepower represents tied up capital.

On the other hand, large units are cheaper than small ones. The quick steam properties of water tube boilers have been men-

tioned. Further, water tube boilers can be forced to much greater overloads than fire tube boilers, and it is sometimes possible to so choose the size of the units that while normally all boilers are used (no spare as such being furnished), yet when one boiler must be cut out for cleaning or other reasons, the others can by forcing them carry the load alone. This is often resorted to when high cost is an objection and water tube boilers are desirable.

The cost of the installation will probably have an important bearing on the selection. Water tube boilers are more expensive than fire tube boilers, but this disadvantage is not as great as may at first appear because the added building space required for the latter offsets this to a large extent.

### LITTLE DIFFERENCE IN COST.

As an example, take the case of a 2,000 B. H. P. installation. At $19 a boiler horse power, the fire tube boilers would cost $38,000. The water tubes at $26 a horse power would come to $52,000, an apparent increase of 37 per cent. The boiler room space in the first case, however, would be 202,000 cubic feet and in the second 120,000 cubic feet. At 11 cents a cubic foot, steel buildings for the first would cost about $22,000 and for the second $13,000. The total cost for the water tube installation ($65,000) would be only 8 per cent. in excess of the fire tube installation ($60,000). In these calculations the costs of boiler setting have been omitted, as these will about balance.

The life of the fire tube boiler is, however, considerably shorter than that of the water tube and it is probable that the water tube would prove cheaper in the end. Of course, if only a short life is expected of the plant and saving on first cost is desirable, the multitubular type would have the advantage.

If ease of erection is to be considered the fire tube is unquestionably preferable. It is self contained in one single shell. The water tube type consists of a number of drums and a greater number of tube sections. While the smaller parts of the latter type may be desirable for handling, the hanging of the large drum with tubes already expanded is a much more simple proposition than the fitting of tube sections.

The sentiment of the operating men in the locality where the plant is to be erected is another factor which should not be overlooked. In the Hawaiian Islands multitubular boilers are the rule, while in Cuba the tendency is toward water tube boilers, and this tendency is steadily increasing.

Multitubular boilers sold by reputable makers are all equally

good. The type is standard and is built by all manufacturers very much alike. Their cost at present writing, complete with water and steam fittings, furnace iron work, etc., will be about $18 to $20 per boiler horse power.

If water tube boilers are selected, the particular type is largely a matter of the personal reference of the designing engineer. The writer has his own ideas on this, but for obvious reasons these cannot be stated here. Cost undoubtedly will influence towards the cheaper boiler, but the structural details should be considered, such as accessibility, ease of replacement of injured or worn out parts, ease of cleaning, circulation, etc. The cost of water tube boilers is between $25 and $27 per B. H. P. It must be understood that the figures here given are approximate only and will vary with the size of the units and other conditions.

As a summary of conditions it might be stated that poor class of labor, low pressure, necessity of low first cost, expected short life of plant and ease of erection are factors which point to multitubular type, while the reverse conditions where low first cost and quick erection are not so important would tend to make the use of water tube types preferable. [R. S. N.]

## BRITISH AGRICULTURAL TRACTORS.*

According to the President of the Board of Agriculture, 1400 tractors had, by October 6, 1917, ploughed 14,500 acres of land for next year's harvest. Three years ago there were probably not 100 tractors in use in the United Kingdom. This progress, though considerable, has not been as rapid as it might have been, owing to the objections raised by farmers against mechanical traction chiefly with regard to compressing the soil and the provision of inadequate power. In some recent models the latter defect is obviated by providing a 30 HP. engine which should suffice for 3-furrow ploughs doing fairly deep work under favorable conditions. British tractors are usually strongly built, and they are therefore very lasting. In time, standardization will be probably arrived at in the various types of tractors, but the final type has not yet been decided upon. There are still numerous problems that remain to be solved by British makers, who are

* From International Review of the Science and Practice of Agriculture, Year IX, No. 6.

at present occupied in delivering the machines that are required for bringing home large areas under cultivation.

British agricultural tractors may be divided into 2 classes, those that are propelled by *a*) steam and *b*) by internal combustion engines. Contrary to the internal combustion engined machines, the steam driven ones follow, save in one or two cases, very closely the design of road locomotives, except they are lighter, the question of weight being of great importance.

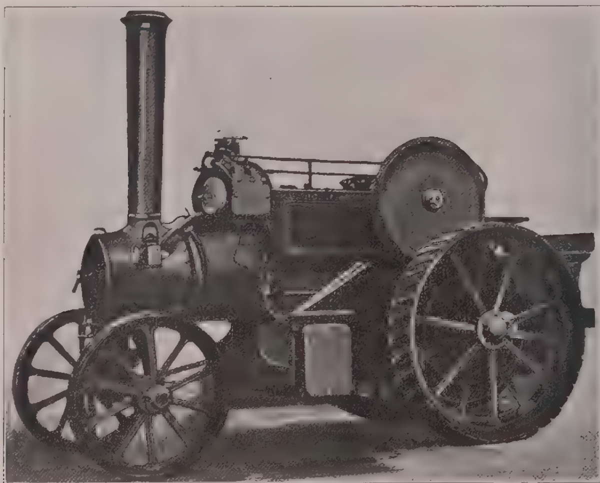


Fig. 1. Aveling & Porter steam tractor.

*Steam Tractors.* The agricultural tractor made by Aveling & Porter, of Rochester (Fig. 1) resembles the road locomotives and rollers made by that firm, but it is smaller and lighter (5 tons). The driving wheels, which are 5 ft. in diameter, are 12 in. wide, but for working on soft ground detachable extension rings 6 in. wide with the necessary spuds are provided.

The engine is of the compound type with 2 cylinders. The boiler has 27 tubes and is fitted with a fire-box of the Belpaire type. The normal speed of the engine is 225 revolutions per minute, and at that speed 21 brake-h.p. is developed at the fly-wheel. The engine is mounted on laminated steel springs fitted to both back and front axles. There are 2 speeds—2½ and 5 miles per hour respectively.

This serviceable little engine will haul a 3-furrow plough under normal conditions. It can cover from 40 to 50 miles per

day on the road, with an approximate cost of from 15*s*. to 16*s*. Coal, or more preferably coke, is the fuel employed.

The tractor (Fig. 2) built by C. Burrell & Sons, of Thetford, has an overall length of 14 ft. 3 in., a width of 5 ft. 8 in., and a height to the top of the fly-wheel of 6 ft. 8 in.; it weighs 6 tons 18 cwt. The boiler is of the locomotive type and has 25 tubes. The engine is compounded with cylinders 4½ in. and 7½ in. in diameter by 8½ in. stroke. It runs at 230 revolutions per minute, developing 20 B. H.P. at the fly-wheel. It has either 2 or 3 speeds, the 3 speeds being 2, 3 and 5 miles per hour. The tractor is furnished with a winding drum which is operated by the engine and carries 60 yards of steel wire rope. It is specially built for farm work.

Fig. 2. Burrell & Sons steam tractor.

Amongst the various engines built by W. Foster & Co., of Lincoln, the 1909 model of the "Wellington" tractor, shown in Fig. 3 may be referred to.

The tractor is of 14-18 H.P., very well built and designed, and can tow an 8-ton load over good roads with gradients up to 1 in 20, while on the low speed gear it will haul the same load up gradients of 1 in 8. The tender contains a water tank of 80 gall. capacity and a coal bunker holding 3½ cwt. Additional tanks are fitted that bring up the total water capacity to 153 gall., which suffices for a journey of some 18 miles under normal conditions.

It is possible that, on account of limitations of weight, the machine requires replenishing with coal and water too frequently to suit farming conditions; the tractor has, however, been successfully used for hauling 3-furrow ploughs.

The same firm also builds a larger steam tractor, specially designed to suit agricultural conditions in the Argentine. The boiler is designed for burning straw; it will haul a plough, serve as a road tractor or drive a Foster threshing machine. The firm of Foster also builds a 40 B. H.P. petrol tractor for use as a general purpose machine. It weighs about 4¾ tons and gives an effective draw-bar pull of 4000 lbs.

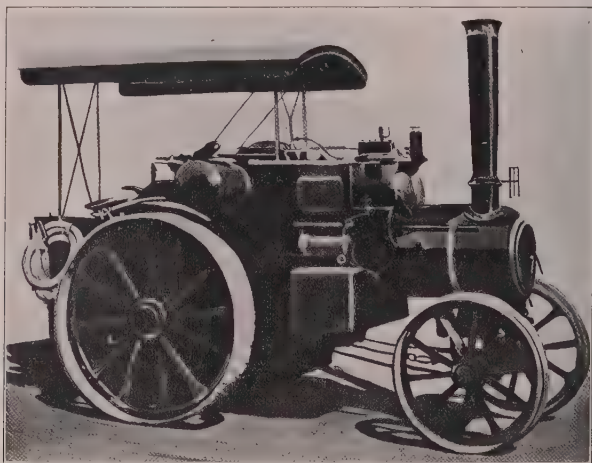


Fig. 3. "Wellington" steam tractor (W. Foster & Co.).

The "Suffolk Punch" steam tractor built by R. Garrett & Sons, of Leiston, is of the horizontal compound type (1). It is intended to perform any agricultural work (Fig. 4) as well as hauling a 10-ton load at 5 miles an hour over fairly good roads. The fire-box is placed in the front of the motor, while the smoke box and funnel are in the rear, so that the driver is very well placed for controlling the vehicle. The boiler is designed so that an inferior quality of coal may be used; the steam is superheated. The engine develops from 37 to 40 B. H.P.

(1) See R., 1916, No. 331. (Ed.)

According to the makers, the average cost of hauling a 4-furrow plough, ploughing to a depth of 6 in. to 7 in., is from 3*s*. 6*d*. to 4*s* 6*d*. per hour, the time taken being from 1½ to 2 hours per acre.

The engine normally runs at 325 revolutions per minute, and there are 2 speeds, namely, a slow speed of 2 miles per hour for ploughing and a higher speed of 5 miles for road work, the engine running at normal speed in both cases. The tractor in full working order weighs about 5½ tons.

The Mann's Patent Steam Cart and Wagon Co., of Leeds, have designed a tractor specially for farm and estate work. This

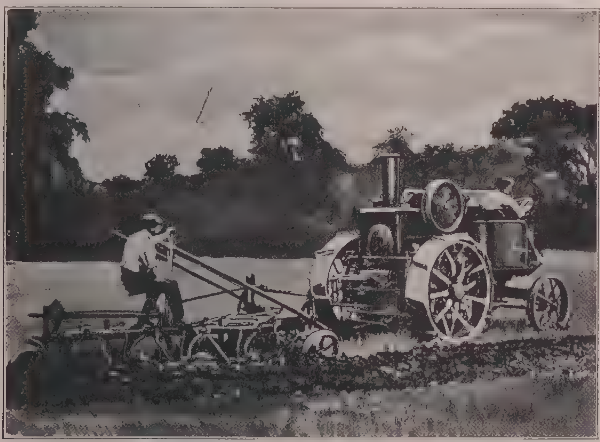


Fig. 4. "Suffolk Punch" steam tractor (R. Garrett & Sons) drawing a plow.

tractor (Fig. 5) has 3 speeds, varying from 2 to 6 miles per hour. The lowest speed is for ploughing in strong land; the intermediate speed for light or medium land, as well as for pulling self-binders, etc., and the quick speed for traveling on the road.

The engine is of the horizontal type, with cylinders 4 in. and 6⅜ in. in diameter by 7 in. stroke. The governor is set to run the engine at 300 revolutions per minute, the speed required for driving ordinary threshing machines. The tractor itself weighs about 4¼ tons, but detachable sideboards are provided so that an extra weight of about a ton can be carried for road work.

On ordinary roads this tractor can haul a 6-ton load; it will

Fig. 5. Mann steam tractor, drawing a plow.

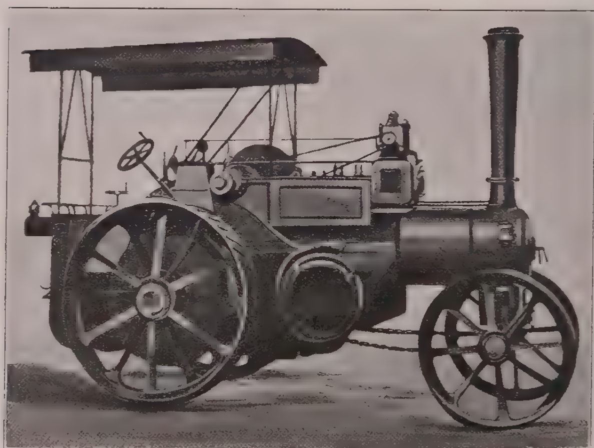


Fig. 6. Maclaren steam tractor.

easily pull a 4-furrow plough in strong clay land. A fair average day's ploughing is 5 acres.

In the tractor made by Messrs. J. and H. McLaren, of Leeds (illustrated in Fig. 6), the boiler is of the usual tractor engine type, with a compound engine, with cylinders 4½ in. and 7½ in. diameter by 8½ in. stroke. There are 3 speeds, namely miles per hour the speed is 324 revolutions per minute, but when ploughing at 2 miles per hour, the speed is 355 revolutions per minute. The machine weighs under 5 tons and is built so as to have a long life. This tractor, provided with a trailer, gained the Royal Agricultural Society's Gold Medal in 1910.

The compound steam tractor made by Ransomes, Sims and Jeffries, of Ipswich, weighs about 4¾ tons. It is of the road locomotive type, and is more especially intended for hauling loads of from 5 to 7 tons on ordinary roads with moderate gradients than for ploughing and similar farm work. The high-pressure cylinder is 4½ in. in diameter and the low-pressure cylinder 7½ in. in diameter, the stroke of both cylinders being 8 in. A by-pass is provided so that high-pressure steam can be admitted to the low-pressure cylinder to provide increased power for starting or emergencies. The engine develops 16-20 H. P. For traveling, 2 speeds, namely, 3 and 5 miles per hour, are provided. The engine is mounted on helical springs to the main axle and laminated springs to the front axle.

Fig. 7. Robey & Co., steam tractor.

The tractor made by Robey & Co., of Lincoln, can haul from 6 to 8 tons on ordinary roads, plough from 10 to 15 acres of average land per day of 10 hours and will drive such machinery as a 4 ft. 6 in. threshing machine.

It is of the usual road locomotive type, but in miniature (Fig. 7). The engine is compound with cylinders 5 in. in diameter by 9 in. stroke. There are 2 traveling speeds, *i.e.*, 2½ and 5 miles per hour.

It is impossible to give any exact figures as to costs of working these tractors, but approximately it may be said that, taking

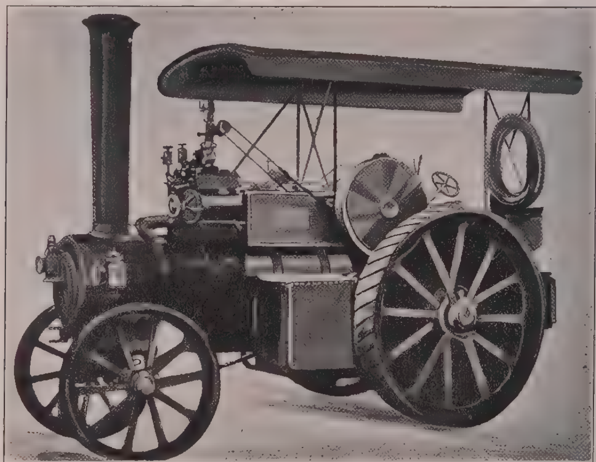


Fig. 8. "Little Giant" steam tractor (W. Tasker & Sons).

coal at £2 per ton, the total cost (wages, fuel, oil, interest, etc.) of ploughing 60 acres in 5 days of 10 hours each is £12. 5*s*. 6*d*. the acre, therefore, costing 4*s*. 1½*d*. per acre.

W. Tasker & Sons, of Andover, make a series of tractors specially designed for agricultural work. The most important model (Fig. 8), the "Little Giant," is a gear-driven steam-tractor; another type is chain driven. Another type has a winding drum for double engine ploughing.

These machines are of the road locomotive type. The engine is of the compound type with cylinders 5 in. and 7¾ in. in diameter by 8 in. stroke, and develops 25 B. H.P. When the machine is to be used for driving fixed machinery, a high-speed governor of the Pickering type is provided. There are 2 speeds,

*i.e.*, 3 and 6 miles an hour. The main gearing runs in an oil bath. The mounting is on the Hoare's spring system.

Wallis & Steevens, of Basingstoke, make the "Wallis" steam motor tractor for universal service. The model (Fig. 9) has been greatly perfected since it was first produced in 1900. It can haul a 6-furrow plough in most soils, and on medium land as many as 9 furrows have been cut with it.

The tractor has a locomotive-type boiler with the 2-cylinder engine mounted on top of it. When running at its normal speed of 400 revolutions per minute it develops 24 B. H.P. The work-

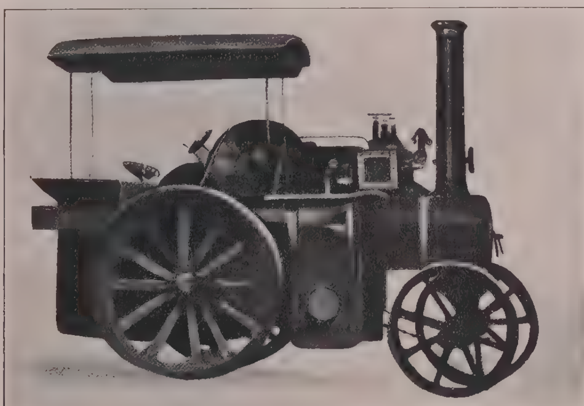


Fig. 9. Wallis & Steevens steam tractor.

ing parts are enclosed in a splash oil bath, and are therefore protected from dirt and dust, while being easily accessible to the driver. Gear changing is easy and the main axle is fitted with a differential motion. The hind axle is fitted with a slip-winding drum. The tender contains a coal bunker and a water tank. The tractor burns coal or coke, but wood may be used.

According to the makers the cost of ploughing an acre works out at just under 11*s.*, while the machine can plough 5 acres a day on the average.

*Internal Combustion Tractors.* Bumsted & Chandler, of Hednesford, Staffordshire, make the "Ideal" (1) tractor (Fig. 10) for general farm use—ploughing, harvesting, road hauling and as a power-plant.

It is driven by a vertical 4-cylinder engine, which develops

(1) See B., 1914, No. 558. (Ed.)

35 H.P. There are 2 speeds forward of 3 and 6 miles per hour and a reverse speed of 3 miles per hour. The hind wheels are furnished with self-cleansing spuds. With a 4-furrow plough, the machine weighs 4½ tons. It is 20 ft. long, with the plough attached, and 6 ft. 6 in. wide. On average land it ploughs one acre per hour.

A long and interesting description is given of the Crawley "Agrimotor," which has been dealt with previously (1).

Motor ploughs of two sizes are built by J. Fowler & Co., of Leeds. In one the engine has a single-cylinder, while in the other there are 2 cylinders. These machines embody the Wyles' patents and also the subsequent inventions and improvements

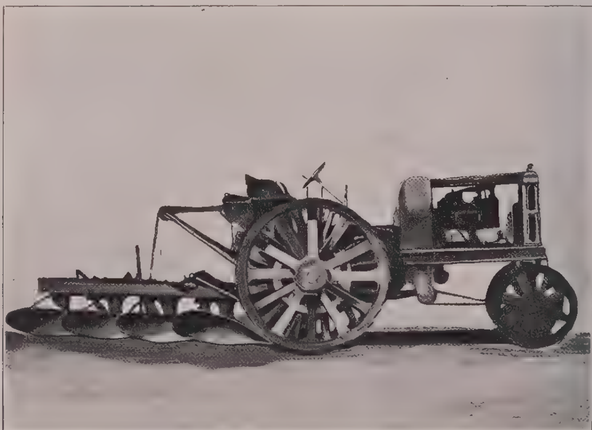


Fig. 10. Bumstead & Chandler motor tractor, hauling a plow.

of J. Fowler & Co. The first type, of 10 H.P. (2), can do the work of 4 horses and is very suitable for work among drilled crops, vineyards, hop gardens, colonial crops, etc.

The 2 cylinder plough (Fig. 11) with a single speed of 1¾ miles per hour, weighs about 21 cwt. It can be fitted with 2 forward speeds of 2.2 and 1.5 miles per hour respectively, and a reverse speed of 1.5 miles per hour. It is slightly longer and wider than the single-cylinder machine.

Its cylinders have a 4 in. bore and 5 in. stroke; it develops

(1) See R., 1917, No. 942. (Ed.) (2) See R., 1916, No. 897. (Ed.)

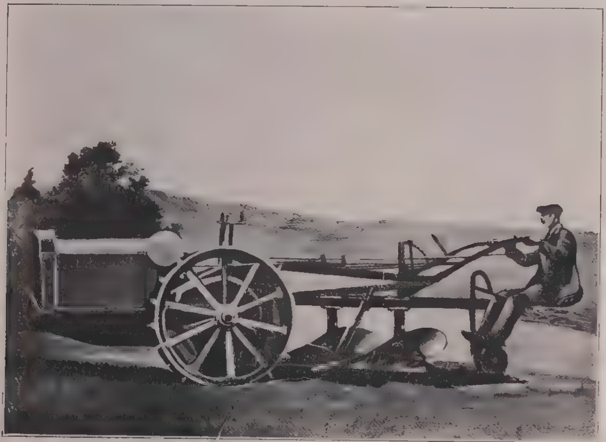


Fig. 11. John Fowler & Co., motor plough.

13-14 B. H.P., with the engine running at from 1000 to 1100 revolutions per minute.

It can either cut one or two furrows; if 2, the width and depth cut is slightly less.

The "Ivel-Hart" tractor, built by the Ivel Agricultural Motors, Limited, is driven by an engine which will work with paraffin, petroleum and other low grade fuels, after starting on petrol.

Fig. 12. "Ivel Hart" motor tractor, drawing a plow.

One of its chief features is (Fig. 12) that it only has one driving wheel, and hence differentiating gearing is not required.

The engine is of 2-cylinders, cast in one piece, with 5½ in. bore and 7 in. stroke, and the normal speed is 600 revolutions per minute (varying from 500-750). At the normal speed the brake horse-power is 22, and the drawbar horse-power 15. There are 2 forward and 2 reverse speeds, obtained by a total of 7 gear wheels and pinions, 5 of which run in an oil bath. Lubrication is of the force feed type. The total weight is 59 cwt., and the length is 12 ft. 8 in.

The machine is self-steering when ploughing. The draw-bar can be adjusted in position. Under average conditions the tractor can haul a 3-furrow plough at a depth of from 6 in. to 8 in.,

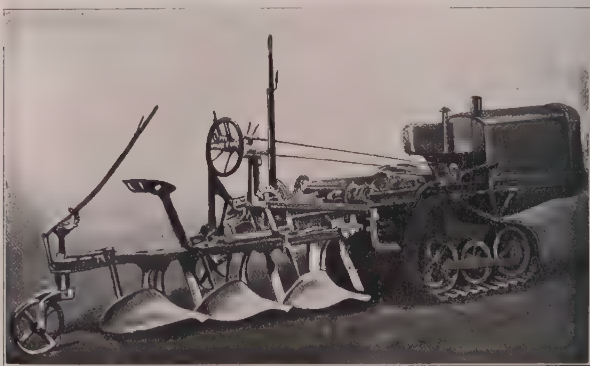


Fig. 13. Martin motor tractor, drawing a plow.

while in heavy soils it will haul a 2-furrow plough cutting from 6 in. to 10 in. deep. It will plough an acre with a 3-furrow plough to a depth of from 6 in. to 7 in. in from 1¾ to 2¼ hours, depending on the nature of the soil and the length of the field. To plough an acre takes from 4 to 5 gallons of paraffin according to the soil.

The motor plough made by Martin's Cultivator Company, Limited, of Stamford, is of the caterpillar type. It is a 3-furrow plough (Fig. 13) and does all the work that can be done by horse ploughing; it can be manipulated by one man.

It can plough 5 or 6 acres a day with a consumption of 2¼ to 3 gall. of petrol. The whole of the plough frame can be detached and its place taken by a wheeled undercarriage, the machine then becoming an agricultural tractor suitable for working

cultivators, drills, harrows, mowers, etc. A pulley for driving machinery can also be attached.

The engine is of the 4-cylinder, 4-cycle type, similar to that used in heavy motor lorries. The cylinders have a bore of 3¾ in. and a stroke of 5 in. At 1000 revolutions per minute the engine develops 25 B. H.P. There are 2 "Zenith" carburetors. The engine is started on petrol and run on paraffin. There is a Dixie magneto and lubrication is effected by a gear-driven wheel pump.

The chain tracks are constructed in accordance with recent patents. Each can be separately adjusted so as to act as land or furrow wheels respectively and also to regulate the depth of plowing. They distribute the weight over a large area of soil,

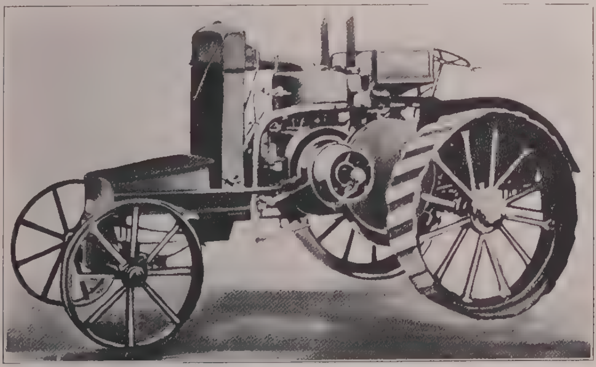


Fig. 14. Saunderson Tractor and Implement Co. motor tractor.

and since the total weight of the motor with a 3-furrow plow is only 30 cwt., the weight per unit of area in contact with the soil is by no means high.

The "Universal" tractor (1), made by the Saunderson Tractor and Implement Co., is well known, but the present model (Fig. 14) is much more simple. The makers have paid great attention to the accessibility of the parts, ease of revenewals and increase of bearing surfaces to give longer life. Before this improved model was placed on the market it was tested for 12 months on some of the heaviest clay in England. The machine proved itself capable of doing the entire work on a 240-acre farm, no horse labor whatever being required.

The "Universal" tractor is of 20-25 B. H.P. It can haul a

(1) See B., 1914, No. 558, and R., No. 897. (Ed.)

3 or 4-furrow plow or other implement, and drive a 4 ft. 6 in. thresher with elevator and chaff-cutter attached. It will haul 5 or 6 tons on the road at a speed of 5 miles per hour. By means of a special coupling it can haul 3 mowing machines, or 2 self-lift binders.

All the working parts of the tractor are covered in; the control mechanism is very simple: the movement of one single lever in front of the driver forwards or backwards controls everything by acting on the governors. The tractor is completely standardized, so that the firm will soon be producing a large number of these British-built machines.

With the object of providing an equipment less costly than the usual steam plant, Walsh & Clark, of Guisely, near Leeds,

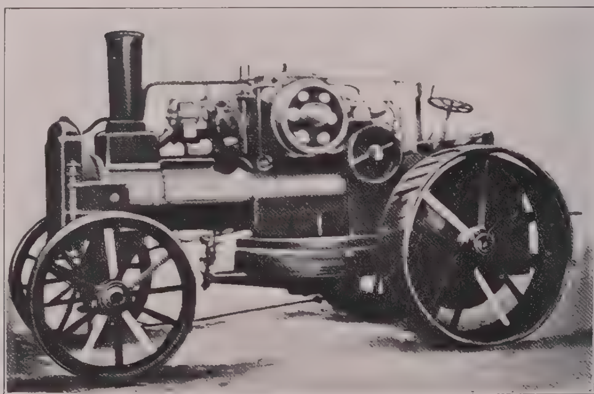


Fig. 15. Walsh & Clark cable motor tractor.

make a ploughing set operating on the cable system, but driven by internal combustion engines, which are started on petrol but run on paraffin. Each engine (Fig. 15) weighs about 6 tons, and is rated at from 30 to 55 B. H. P. at an engine speed of 200 revolutions per minute, and when traveling or plowing, and 22 B. H. P. on the driving belt.

The engine is of the horizontal type, with 2 cylinders, and gives a continuous pull on the ropes of 3500 lbs. It will haul a 4-furrow plough on medium or light land, and a 3-furrow plow on heavy land. A pair of engines can plow from 7 to 10 acres per day of 10 hours, according to the nature of the land, and with rope speeds of from 250 ft. to 350 ft. per minute.

They will also cultivate from 14 to 20 acres per day. The machine can be employed as a tractor for road or field work.

Messrs. W. Weeks & Son, of Maidstone, make the Weeks Dungey "New Simplex" tractor (Fig. 16), intended for all-round farm work. It starts on petrol, but runs on paraffin; there are 3 speeds, *i.e.*, 4½, 2½ and 1¾ miles per hour. It has cut 24 acres of corn per day with an ordinary 5 ft. binder, and 27 acres with a 6 ft. machine.

The "New Simplex" tractor has 4 wheels and weighs 35 cwt. It is 8 ft. long, 4 ft. wide and 5 ft. 6 in. high and develops 25 B. H. P.

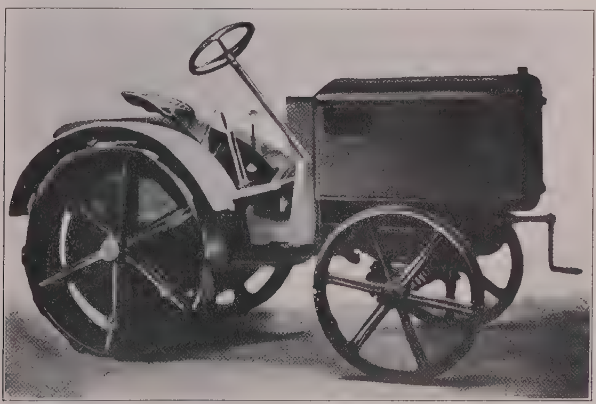


Fig. 16. "New Simplex" motor tractor (W. Weeks & Son).

The machine is very well constructed and fitted with all the latest improvements. In Kent, it has ploughed from 2½ to 3 acres per day, at a cost of about 12*s*. per acre.

The Wyles motor plow has been described in this *Review*, March 1918, No. 332. Fig. 17 shows it hauling a mowing machine.

The latest tractor built by Messrs. Clayton & Shuttleworth, of Lincoln, is of the chain track type, and a woman can manipulate it, with a plow attached. The tractor delevops 35 H.P. and it can haul a 3 or 4-furrow plow.

The engine has 4 cylinders, each of 120 mm. bore and 140 mm. stroke. Petrol is used for starting and paraffin for running. The mechanism is easily accessible. Two forward speeds of 1¾ and 4 miles per hour and a reverse of 3 miles per hour are provided, while the necessary mechanism is actuated by

Fig. 17. Wyles motor tractor hauling a mowing machine.

straight-through lever control. The chain tracks have received a good deal of attention. The weight of the tractor is carried on each side by 4 rollers.

The draw-bar pull is 2 tons in slow gear. For the driving of machinery there is a belt pulley. The tractor weighs 2 tons 16 cwt. It is 11 ft. long, 5 ft. 4 in. wide and 5 ft. 6 in. high. The British Government has ordered large numbers of these tractors.

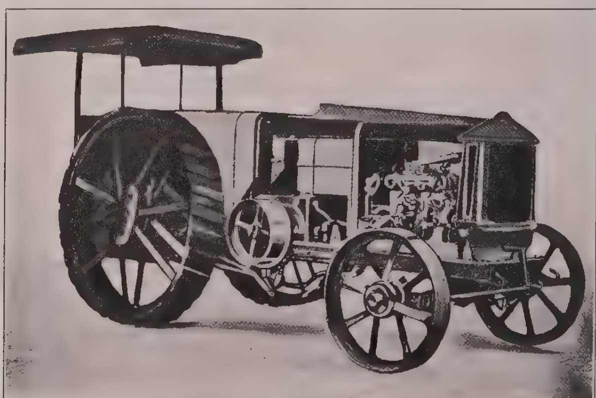


Fig. 18. Alldays & Onions motor tractor.

The Alldays & Onions Pneumatic Engineering Co. make a tractor carried on special springs for road work, the springs being clamped down for field work.

Fig. 18 shows the tractor, which is for all-round work. It has 3 speeds forward and a reverse; the highest road speed is 5 miles per hour and the slow speed is 1½ miles per hour for difficult plowing and 2½ for ordinary plowing.

The engine is vertical, 4-cylinder, and runs at 1000 revolutions per minute. A Zenith carburetor, arranged to work with paraffin, is provided. The crankshaft is carried in 3 bearings lined with anti-friction metal. There is a high-tension Dixie magneto, and steering is by the Ackermann system. The tractor will turn in a circle having a diameter of 28 ft. It is provided with a winding drum, carrying 50 yards of steel wire rope. The present wheel base of the tractor is 7 ft. 10 in., but it is to be reduced to 7 ft.

The tractor has been tested in Scotland and also at Birmingham where it drew a 3-furrow Howard gang plow. The drawbar pull was about 1100 lbs. on the average.

For use in driving machinery, an 18-in. pulley is provided; it can drive a 4 ft. 6 in. threshing machine.

Besides the detailed description of the various British tractors, an account is given of the "Tracford" (1) appliance, intended to convert a Ford or other car into a 20 H.P. agricultural tractor. There are 3 steel land wheels, provided with detachable spuds.

## THE SCIENTIFIC USE OF BAGASSE AS FUEL.*

One of the most interesting papers read before the recent meeting of the Hawaiian Sugar Planters' Association in Honolulu was that of Mr. A. Gartley on "Bagasse Designs and Furnace Control." We have been students of bagasse burning for more than half a century and have seldom previously found as clearly cut and definite statements of the merits and demerits of the methods of bagasse burning as those brought out by Mr. Gartley and based upon his own experience, and that of Mr. Johnson, a Hawaiian sugar chemist, freely quoted by Mr. Gartley.

In the earlier history of the sugar industry it was quickly found

(1) See R., April 1918, No. 455. (Ed.)
* Louisiana Planter, Jan. 11, 1919.

that the cane fiber could be made to do a large part of the cane juice evaporation into sugar crystals. The industry was a tropical one and the tropical sun was used to sun-dry the bagasse. With slave labor in the tropical countries the work was done by hand, and where cheap labor can be had it is done that way at the present time in some of the smaller factories, in Barbados for instance.

As during the last fifty years nearly all the improvements and economics in cane sugar manufacture have originated in Louisiana, we shall utilize some Louisiana data in urging the soundness of Mr. Gartley's twentieth century conclusions. Louisiana sugar cane will supply about ten per cent. of dry fiber. Our old single cane mill secured about 60 per cent. of cane juice and 40 per cent. of bagasse, 40 pounds of bagasse containing 10 pounds of fiber and 30 pounds of juice. Such bagasse would not burn without drying, and some of our sugar planters, because of the humid and rainy climate, erected drying sheds incurring enormous labor expenses. The bulk of the bagasse, however, was hauled away to a dumping ground and there burned in the open when convenient.

These results led to experiments with five-roller and six-roller mills, but still bagasse burning direct from the cane mill was not a success. The McDonald hydraulic cane mill pressure regulator finally made this multiple milling a success and the result was 70 per cent. extraction of cane juice of the weight of the cane with a six-roller cane mill in 1873, erected on his Belair plantation by the writer, the first six-roller cane mill erected under the new free labor regime in Louisiana. This 70 per cent. extraction left 30 pounds of bagasse per 100 pounds of cane and in the bagasse 10 pounds of fiber and 20 pounds of cane juice. This bagasse would burn well in properly built furnaces and started a new era in utilizing bagasse direct from the mill as fuel. At Evan Hall in Ascension parish a similar furnace was then built and did well, but still better was desired.

In the late seventies some immense cane mills were built, but their roll diameters were too great and the bagasse came through wet. We then constructed a nine-roller mill at Belair, feeding cane on the basis of 300 tons per day and we secured 75 per cent. extraction in normal juices of the weight of cane, using pressures of 100 tons on the first mill, 125 tons on the second mill, and 150 tons on the third mill. We then had but 25 pounds of bagasse containing 10 pounds of fiber to 15 pounds of juice.

There are very few cane mills that do any better than this. We made better bagasse than any competing six-roller cane mill of which we knew, but the new heavy six-roller mills ground from two to three times as much cane per day. With hot water sat-

uration we at times got two or three points better extraction. We find the best cane mills now of nine rolls or more and with crushers getting 80 per cent. extraction of the contained juices in their practice, and the still larger mills claim to get still more. Seventy-five per cent. extraction will leave bagasse that burns finely.

Mr. Gartley in his paper says that the drier the bagasse the better it will burn. In a general way this is true, but our readers will notice that in Mr. Gartley's paper, which is published in this issue, he indicates that the furnace heat should be maintained at the highest practicable temperature, and that any excess of air should be avoided. This high temperature is a *sine qua non* in bagasse burning. This fact was brought out in the Thompson bagasse burner patented some sixty years ago, and a double furnace of this kind was built at North Bend plantation on Bayou Sale, St. Mary's parish. The furnaces were large and when one was pretty well filled up the bagasse was turned into the other furnace. This gave some time for drying before burning, the advantage of which Mr. Gartley refers to.

Professor Silliman of Yale University back in those days is quoted as saying that under certain conditions wet fuel was better than dry. Water, composed of one molecule of hydrogen and two of oxygen, disassociates these elements at about 2200 F. In burning bagasse if the temperature be high enough the hydrogen and oxygen of the water in the bagasse separate and seek new combinations, the oxygen combining with the carbon of the bagasse and forming carbon dioxide, and the free hydrogen combining with any excess carbon, forming carburetted hydrogen, an inflammable gas. Certainly those bagasse furnaces maintained at a white heat are the most successful.

Our reader will note the point made by Mr. Gartley as to the necessity for bagasse distribution so that there shall be no hole in the bed of burning bagasse to admit an excess of air. Our Louisiana inventor, Mr. Fisher, has covered the distribution point and a number of feeding devices exclude as far as practicable any excess of air.

One feature of bagasse burning is not generally known. The Mr. Thompson, who utilized the wet fuel idea, was a New York State man with experience in burning wet tan bark direct from the tanning vats with the water still dripping from it. A casual observer would have said that the burning of such stuff was almost impossible and of no industrial importance. Mr. Thompson doubtless knew of the old-fashioned air furnaces for melting cast iron without any blast, and knew of the advantages of low fire-

brick arches and furnace crowns, and knew what they would do when white hot.

We have seen these tan bark furnaces in operation and they do successful industrial work. The secret of their success lies in the hard and more or less impermeable character of tan bark. It is made of the hard dry bark of trees and is not built up as is sugar cane with soft cellular structure of a sponge-like character. We have tested it by taking 100 ounces of each, of normal fuel condition of tan bark and of 75 per cent. extraction bagasse and have found the residue dry matter or fiber after steam oven drying to be about 50 per cent. greater in the tan bark than in the bagasse. The wet tan bark contains less water and more fiber than does good bagasse, and hence the greater difficulty in burning bagasse. The furnace at white heat is imperative in the successful burning of bagasse fuel. [R.S.N.]

## VELOCITY OF FLOW THROUGH TUBULAR CANE JUICE HEATERS.*

By J. O. Frazier.

Sugar cane juice heaters may be divided into two general classes which will cover all usual practice. These may be designated as the tank and the tubular, which terms will broadly describe their elementary structure. The tank class may embrace all those in which steam coils, or pipings, are submerged in the juice; the tubular class, all those in which juice filled tubes are immersed in steam or other gaseous heating medium. Circulation, "velocity of flow," in the case of the tank heater, is practically one of gravitation, is low at best, and not under control. In the tubular heater, with its forced circulation and properly proportioned "pass" area, the very important benefits derivable from high speed liquor movement may be obtained in its fullest measure.

Aside from rapid circulation, which is quite the most important of operative features, there are other justifying causes for the general change from the tank to the tubular heater. The most apparent of these are the continuity of the process, lower radiation losses, compactness of structure and diminished attendance cost; the most important, controllable speed of circulation, is

* Louisiana Planter, Jan. 11, 1919.

discussed further along. In the earlier stages of introduction, a superior steam economy, for the tubular heater, was claimed with rather unwarranted liberality. As between the two, on the score of heat economy, there is not a great deal to choose; other things equal, this depends upon drainage and radiation heat losses, both rather in favor of the tubular heater. Regarding heat transmitting capacity there is very much to choose, this in favor of the tubular heater and almost wholly due to circulation. In general design the tubular heater represents what may easily reach the highest economic achievement in juice heating where properly proportion for its duty.

The heat transmission possibilities of rapid circulation have been very sparingly availed of, in the most general proportions of the tubular cane juice heater. A tolerably uniform "pass" area has prevailed that has the appearance of some concerted acceptance of approximate proportions. The general result of such proportions is that the average velocity is found to be about half of what is easily demonstrated as much superior. In fact, average velocity seems rather an incident of mechanical convenience than as an end calculated for. Without fixing definite limits as to what might be called high and low velocities, those that fit observation and subsequent arguments based thereupon, would be two hundred and fifty, and six hundred feet per minute flow through the tubes respectively.

Rather as an application of common sense than of technics, it is here intended to illustrate extremes in velocity, with their respective effects, and to analyze some operative factors indicating the propriety of higher than usual velocities. The structural element upon which this is based, that of tube grouping, or "pass" area, is unpatented, unpatentable and free to all who can shake off mechanical tradition.

The basic element of value, with all heating surfaces, is the coefficient of heat transmission. The profit earning ratio is in direct proportion to this factor. This resolved into its two components show them to be, first, the nature of the heat conducting vehicle-tube or plate, as a heat conductor, and, second, the frequency of position change of the heating medium and the absorbent upon the surfaces—circulation. The total earning power will be the above plus temperature difference between the heating medium and the absorbent. Steam economy, previously referred to, is a thing quite apart from heating capacity work. Other conditions equal and radiation loss and heat discharged with the condensate the same, all steam juice heaters would be of equal economy.

For maximum earning power we must get the highest coeffic-

ient of heat transmission, and the greatest temperature difference that is practicable. For the former we must have the best available heat conductor among commercial metals—namely, copper; this must be clean. Given these conditions, the coefficient of heat transmission will then rise in some regular proportion as the rapidity of position change between the heating medium and the absorbent increases. With given conditions for all the above, the total heat transmitted will be in direct proportion to the temperature difference. High-priced copper heating tubes are entitled to all the above favorable conditions in their fullest obtainable measure; so is their owner.

Generally low steam pressures will not give such heat transmitting capacity as we ought to get from copper surface, except it be in the utilization of some sort of by-product heat, like exhaust, and this only when there is a surplus over other requirements in evaporation or otherwise. Even then, and with a surplus exhaust, juice heating ought to be in two separate stages, first with exhaust, then later with live steam and this as high in pressure as the conditions require or the juice heater calandria be capable of handling with safety. This to get more work out of a given unit of surface.

Orrok's experiments, under conditions very closely paralleling those in cane juice heating, indicated the conclusion that the coefficient of heat transmission, other things equal, is as the square root of the velocity in feet per minute; this, in the present case, applies to the absorbent—juice. His experiments covered velocities from three hundred to seven hundred feet per minute, and developed a uniformity that, for practical purposes may be stated as a law. Taking his conclusions for comparison of relative heat transmission ratios, we would find that the heat transmission value for the two hundred and fifty feet per minute—as above—would be fifteen, even figures, and that for the seven hundred feet per minute would be twenty-six in even figures.

The general correctness of some such conclusion is indicated in many of the common circumstances of everyday life, based upon the same factor—circulation. For instances, consider the varying cooling power of the electric and even hand fans, at varying speeds. If one stands upon an open moving train at high velocity the heat absorption is so great as to make a much cooler feeling than the air really gives. The demand for heat, by the absorbent—moving air—is so great that our exposed person, as the radiator of heat, can't keep up the supply.

The general conception of what is the best economical velocity of juice flow through the heater tubes is somewhat indefinite, most likely in its exact measure not known. Few modern experi-

ments seem to be recorded along this line. In order to illustrate a secondary, but important, result of high velocity—that of continued cleanliness of surface—the two following extremes in velocity are given, both taken from actual observation, both territorially very close together. In neither case was the opportunity offered to test the leading feature—relative coefficient of heat transmission.

A very common proportion for a thousand-ton—(tons) per day—juice heater in Louisiana is one with eighty-eight tubes, two inches outside diameter and four tubes to the "pass." These tubes are of such length as to give, to the heater, nominally five hundred square feet of heating surface, one-half square foot per ton of cane. One of such heaters was found in a sugar factory where but three hundred and fifteen tons of cane were ground per day, twenty-four hours; the resultant velocity of flow through these tubes was very approximately seventy-six feet per minute. This heater was observed, at the end of the grinding season, to be the foulest that ever came to the writer's notice; it was not spoken of as a good heater, it was a misfit—too large.

In the immediate neighborhood of the above there was installed a juice heater, some time later, in which the writer was instrumental in fixing the pass area. This heater was to handle the juice from eleven hundred tons of cane; there were three one and one-half-inch tubes to the "pass," and the resultant velocity was approximately six hundred feet per minute. This heater was also observed, at the end of its grinding season, during which eighty-five thousand tons of cane had been ground. The heater was reported not to have been cleaned during the season beyond flushing with water after each run. The tubes were perfectly clean and brighter than when first installed.

Accepting Orrok's mandate as to relative heat transmission, the low-speed heater, above mentioned, had a transmission value—primarily of 8.7 but did not maintain that. The high-speed heater had a primary heat transmission value of 24 and maintained it throughout the season. Apparently it would have done so, with equal conditions, indefinitely. These facts seem to lead to the conclusion that either the maintenance of primary efficiency, or increased heat transmission ratio alone would warrant the adoption of high velocity.

Recognizing the defective proportion of the standard thousand-ton heater as first described, even for a thousand-ton duty, an engineer friend of the writer suggested the plugging of half the tubes in each "pass." This would double the velocity, the first end sought, but would cut in half the time element of exposure, also the heating surface in half. From

this it appears that defective design is irremediable; velocity, path length and time exposure must be calculated for. There are two factors amenable to circulation treatment with the steam heated juice heater; the liquor in the tubes and the steam that surrounds them. As between these two the treatment for steam circulation is of infinitely less importance than that of the liquor; one will find its place, the other must be forced.

Aside from velocity of flow, temperature difference, character of conducting metal, even of its cleanliness, there comes into the heat transmission ratio the factors of smoothness of tube walls and pressure against same. Dealing only with inner tube walls, we may consider that there is always a film of static temperature upon the sides of all heating surfaces. Of course, the thinner this film, other things equal, the greater the heat flow. This film may consist of particles of quiescent liquor lodged in the interstices of metal surface, or of scale thereon. It may partly consist of clinging bubbles of non-conducting steam, or vapor. Again, it may be contributed to by stratification of the flowing juice, where that against the sides does not properly mix with the cooler core. Efforts have been made to give a spiral flow of juice through the tubes; this is theoretically correct, but its quantity undetermined so far as has come to the writer's notice. The greater the number of transits through the heater in the juice path, the better the mixing. The higher the velocity of flow and the greater the pressure against the tube walls the thinner this static film becomes.

From all the above a conclusion may safely be reached that clean copper tubing, with high velocity of flow, high pressure against the tube walls and high temperature difference are to be sought for the best economic effect from tubular cane juice heaters. Confirming these requisites, are the following observed facts of two comparative cases.

In the case of the high speed heater, above referred to, the duty obtained, in heat transmission per unit of surface was very approximately two hundred and ninety-seven heat units —B. T. U.'s—per square foot of heating surface per hour per degree temperature difference. A later observation was made in a large industrial plant where there were cast-iron heating surfaces—none too clean surfaces—and excessively low velocity of flow; the result was slightly less than one B. T. U. per square foot per hour per degree temperature difference. Mean temperature differences were calculated for in both cases. In the latter case, the total heat recovery—

from flue gases applied to boiler feed water—was quite good; entering gases were 519 degrees F., and discharge gases at 225 degrees F. The first cost and attendance costs of this "economizer" were very high; total performance excellent—unit performance execrable. This low duty was, apparently, due wholly to poor conducting material, lack of cleanliness and low circulation. Also, all the circumstances of that case indicated that the fault lay almost equally among these three adverse conditions. [R. S. N.]